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SEATTLE–TACOMA AIR POLLUTANT EMISSION INVENTORY

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A report is presented of the emission inventory on the Seattle-Tacoma metropolitan area. The report, which is intended to determine the present level of emissions and status of their control, provides estimates of total emissions of oxides of sulfur oxides of nitrogen, hydrocarbons, carbon monoxide and particulate matter. The emissions are delineated with respect to source type, season of the year, and geographical distribution within the area. The study area is divided into grid zones that serve as the basis for locating sources and reporting their emissions. The inventory included emission sources; fuel combustion, transportation, refuse disposal, and industrial processes.

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PUBLIC HEALTH SERVICE
Consumer Protection and Environmental Health Service
National Air Pollution Control Administration
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1. Puget Sound Air Pollution Control Agency
2. Washington State Air Pollution Control Board

TABLE OF CONTENTS

Page

PREFACE.....1

INTRODUCTION.....3

SUMMARY OF EMISSIONS.....5

STUDY AREA.....8

GRID COORDINATE SYSTEM.....12

DISCUSSION OF RESULTS.....15

Fuel Combustion by Stationary Sources.....15

Transportation Sources.....17

Refuse Disposal Sources.....19

Industrial Process Sources.....20

Point Source Emissions vs. Total Emission.....21

METHODOLOGY.....36

Fuel Consumption by Stationary Sources.....36

Transportation Sources.....37

Refuse Disposal Sources.....38

Industrial Process Sources.....38

TOTAL EMISSIONS BY GRID.....62

REFERENCES.....77

TABLES

		Page
Table 1	Total Emissions by Category	7
Table 2	Population Characteristics of Seattle-Tacoma Study Area	10
Table 3	Number of Industrial Establishments in Seattle-Tacoma Study Area	11
Table 4	Fuel Oil Consumption by Political Jurisdiction	22
Table 5	Coal Consumption by Political Jurisdiction	23
Table 6	Natural Gas Consumption by Political Jurisdiction	24
Table 7	Chemical Analysis of Fuels	25
Table 8	Summary of Domestic Heating by Number of Dwelling Units in Study Area	26
Table 9	Summary of Emissions From Burning of Fuels in Stationary Sources	27
Table 10	Vehicle-Miles Traveled in Seattle-Tacoma Study Area	28
Table 11	Gasoline and Diesel Fuel Consumption	29
Table 12A, B, C	Air Traffic Activity at Three Major Airports	30 & 31
Table 13	Summary of Transportation Emissions	32
Table 14	Refuse Disposal Balance in Study Area	33
Table 15	Solid Waste Emissions	34
Table 16	Summary of Emissions From Industrial Process Emissions	35
Table 17	Summary of Total Emissions From Point Sources	41
Table 18	Summary of Area Source Emissions by Season for Study Area	47
Table 19	Total Emissions by Grid	62

Figures

		Page
Figure 1	Seattle-Tacoma Study Area	4
Figures 2 & 2A	Seattle-Tacoma Study Area Coordinate System	13 & 14
Figures 3 & 3A	Point Source Locations for Study	39 & 40
Figures 4 & 4A	Sulfur Oxide Emission Density From All Sources	67 & 68
Figures 5 & 5A	Particulate Emission Density From All Sources	69 & 70
Figures 6 & 6A	Carbon Monoxide Emission Density From All Sources	71 & 72
Figures 7 & 7A	Hydrocarbon Emission Density From All Sources	73 & 74
Figures 8 & 8A	Nitrogen Oxide Emission Density From All Sources	75 & 76

PREFACE

This report, which presents the emission inventory of the Seattle-Tacoma metropolitan area, is another in a series of studies outlining the sources and emissions of air pollutants for major metropolitan areas in the country. These reports provide estimates of total emissions of oxides of sulfur, oxides of nitrogen, hydrocarbons, carbon monoxide and particulate matter. The emissions of these pollutants are delineated with respect to source type, season of the year, as well as their geographical distribution within the area. These surveys are also intended to determine the present level of emissions and status of their control in metropolitan areas.

The general procedure for these surveys is based on the rapid survey technique.[1] The Study Area is divided into grid zones that serve as the basis for locating sources and reporting their emissions. All sources of pollution are classified into two general groups, i.e., point sources and area sources. All sources that emit large quantities of air pollutants are considered individually and located specifically within the Area. This latter group, which generally contains about fifty to one hundred sources, typically includes large industries, power plants, and refuse burning facilities. The remaining sources are considered collectively as area sources and their

emissions are reported as totals for grid zones. This category includes motor vehicles, home heating, smaller industries, on-site refuse burning, etc. The emission, in both cases, are expressed in terms of tons of pollutant per average annual, summer and winter day.

Emissions for the most part, are extimated using various indicators of pollutant emissions and average emission factors that are related to these. This means that information and data are collected on fuel consumption and refuse burning rates, vehicle miles and gasoline consumption as well as various industrial production rates. These are then translated into emission estimates by use of average emission factors. These factors, for the most part, represent average emission rates for a particular industry or fuel type. Because of the inherent differences in type of equipment, operating rates, control equipment, and efficiency of operation among the plants and fuel users within a given category, the application of the emission factors to any individual plant or even a smaller number of similar plants or processes may result in a discrepancy between the actual and the estimated emissions. However, the estimates of total pollutants from all sources in the study area should be fairly accurate.

INTRODUCTION

The information and data presented in this report were gathered in cooperation with the Washington State Air Pollution Control Board and the Puget Sound Air Pollution Control Agency during a survey conducted in October, 1968. The data obtained in this study is for the most part, representative of 1967 and emission estimates presented herein should be considered as describing the levels and conditions during 1967.

For purposes of this survey, a Study Area consisting of ten counties surrounding the Puget Sound was selected. The Study Area includes two Standard Metropolitan Statistical Area (Seattle and Tacoma) and five other cities with populations in excess of 25,000. The entire Study Area covers some 15,000 square miles and included a 1967 population of about two million people.

The Study Area was subdivided into 132 grid zones ranging in size from 25 square kilometers in the heavily populated and industrialized areas to 1600 square kilometers in the outlying areas. In all, four differenct sizes of grids were used. Although specific individual source information was obtained for over 95 sources, only the largest 52 were considered as point sources. These 52 sources are the most significant emitters of air pollutants in the Study Area.

Figure 1. Seattle-Tacoma Air Pollution Study Area

Summary of Emmissions

An estimated 1,400,000 tons of the five major pollutants are emitted annually in the Study Area. Breakdowns of this total with respect to specific pollutnats as well as the type of sources emitting these pollutants are given in Table 1 and briefly summarized below.

Emmissions by Type of Pollutant

Oxides of Sulfur:	Total tons per year =283,000
	Industrial Process losses = 82%
	Industrial fuel to use = 12%
	Other = 6%
Particulates:	Total tons per year = 34,500
	Industrial process losses = 28%
	Road vehicles = 24%
	Refuse disposal = 18%
	Industrial fuel use = 17%
	Residential and Commercial fuel use = 7%
	Other = 6%
Carbon Monoxide:	Total tons per year = 907,100
	Road vehicles = 95%
	Refuse disposal = 4%
	Other = 1%

Hydrocarbons:

Total tons per year = 171,200

Road vehicles = 45%

Evaporation = 33%

Industrial fuel use = 14%

Other = 8%

Oxides of Nitrogen:

Total tons per year = 75,500

Road vehicles = 69%

Industrial fuel use = 15%

Refuse disposal = 5%

Residential and commercial fuel = 4%

Other = 2%

Emissions by Point Sources

Oxides of Sulfur	72%
Particulates	43%
Carbon Monoxide	1%
Hydrocarbons	14%
Oxides of Nitrogen	16%

TABLE 1 SUMMARY OF AIR POLLUTANT EMISSIONS IN THE SEATTLE AREA
1967 (tons/year)

Type	Sulfur Oxides	Partic-ulates	Carbon Monoxides	Hydro-carbons	Nitrogen Oxides
Transportation	7,280	10,160	872,360	136,940	54,450
Road Vehicle	4,700	8,300	861,500	77,000	51,700
Evaporation	--	--	--	56,600	--
Other	2,580	1,860	10,860	3,340	3,750
Combustion of Fuels From Stationary Sources	45,570	8,160	2,010	24,510	14,980
Industrial	35,090	5,480	220	23,650	11,660
Steam Electric	Neg.	Neg.	Neg.	Neg.	Neg.
Commercial Institutional	1,600	820	1,410	330	490
Residential	8,880	1,500	380	530	2,830
Refuse Disposal	200	6,360	32,740	3,060	4,160
Incineration	50	250	1,080	--	50
Open Burning	150	5,960	31,660	1,860	4,100
Tepee Burners	10	150	--	1,200	10
Industrial Process	231,000	9,800	--	6,700	1,900
Grand Totals	283,050	34,480	907,110	171,210	74,490

STUDY AREA

As shown in Figure 1, the Study Area encompasses the entire Puget Sound Region and includes the following ten counties: (1) Clallam, (2) Jefferson, (3) King, (4) Kitsap, (5) Mason, (6) Pierce, (7) Skagit, (8) Snohomish, (9) Thurston, and (10) Whatcom. Although its total area is slightly over 15,000 square miles, only some 200 square miles are at present urbanized. Over 80 per cent of the Study Area's 1967 population of 2 million were residing in the three urban counties of King, Pierce and Snohomish. These three counties also constitute the two SMSA's of the Study Area-Tacoma (Pierce Co.) and Seattle-Everett (King and Snohomish). The 1960 and 1967 population of each of the ten counties are presented in Table 2. Comparison of 1960 and 1967 population shows an increase of 10.9 per cent for the United States during the same period.

The major manufacturing industries of the Area are those concerned with aircraft and the pulp and paper. In addition, several large refineries, aluminum reduction plants, metal smelting working establishments are located within the Study Area. Because of the availability of hydro-electric power, the Study Area is notably void of large fossil fuels electric generating plants. The number of establishments by industrial category for 1960 are summarized in Table 3.

The Cascade Mountains to the east and the Olympic Mountains to the west cause the region to be characterized by equable temperatures and heavy precipitation. The prevailing southwesterly circulation keeps the average winter temperatures between thirty and forty degrees, and the summer temperatures in the seventies or eighties. The winter and spring months are characterized by considerable rainfall. More than 75 per cent of the yearly average precipitation occurs from October 1 through March.

TABLE 2 POPULATION FIGURES FOR SEATTLE-TACOMA STUDY AREA

Political Jurisdiction	1960	1967	Percent Increase
Clallam County	30,022	33,588	+ 11.8
Jefferson County	9,639	10,037	+ 4.1
King County	935,014	1,051,692	+ 12.4
Kitsap County	84,176	96,683	+ 14.8
Mason County	16,251	18,220	+ 12.1
Pierce County	321,590	378,298	+ 17.6
Skagit County	51,350	53,184	+ 3.6
Snohomish County	172,199	224,406	+ 30.3
Thurston County	55,049	64,591	+ 17.3
Whatcom County	70,317	76,605	+ 8.9
Total Study Area	1,745,607	2,007,304	+ 14.9

Table 3 NUMBER OF ESTABLISHMENTS IN THE SEATTLE STANDARD METROPOLITAN STATISTICAL AREA (1960)

Food and Tobacco	148
Textile Apparel	44
Chemical and Petroleum	88
Lumber and Wood	173
Stone, Clay and Glass	48
Primary and Intermediate Metal Products	76
Electrical Machinery	69
Transportation and Ordinance	39
Paper and Printing	91

GRID COORDINATE SYSTEM

Grid coordinates based on the Universal Transverse Mercator System were used in this study to show the geographical distribution of sources and emissions. As shown in Figure 2, the entire Study Area was divided into 132 grids of four different sizes--25 sq. km., 100 sq. km., 400 sq. km., and 1600 sq. km.

Different size grids are used to limit the number of grid zones and yet allow a satisfactory definition of geographical gradation of emissions in areas where the majority of pollution occur. For this reason, the 25 sq. km. grids are used in the downtown areas, where the density of emissions changes abruptly within short distances. In areas primarily rural in nature, the use of small zones are not as important.

As illustrated in Figure 2, each grid line is identified by a coordinate number. The north-south and the east-west coordinates are expressed in meters. The point sources are identified by both X and Y coordinates to the nearest 100 meters. The grids are identified by the X-Y coordinates of the geographical center of the grid zone.

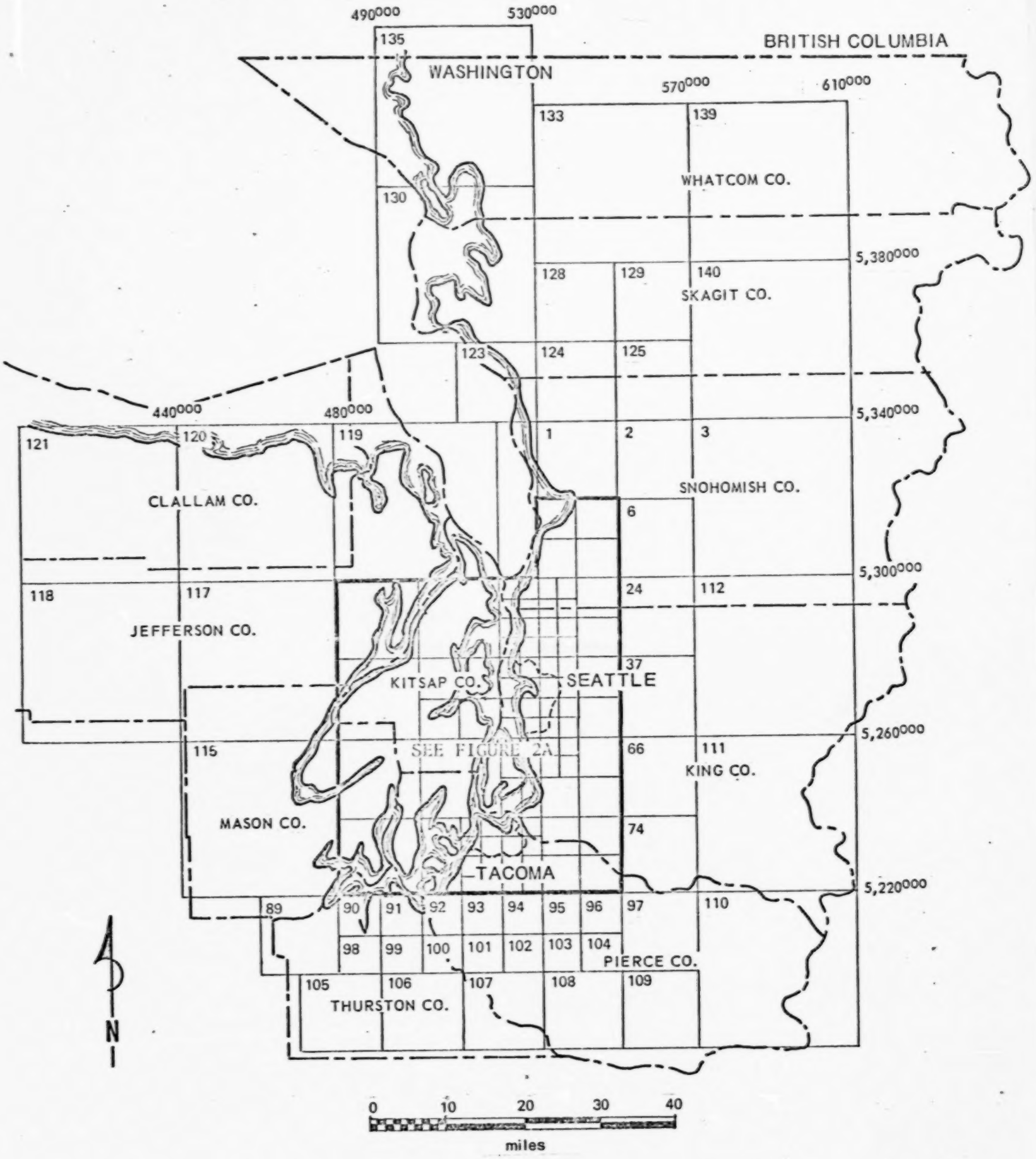


Figure 2. Seattle - Tacoma air pollution study area.

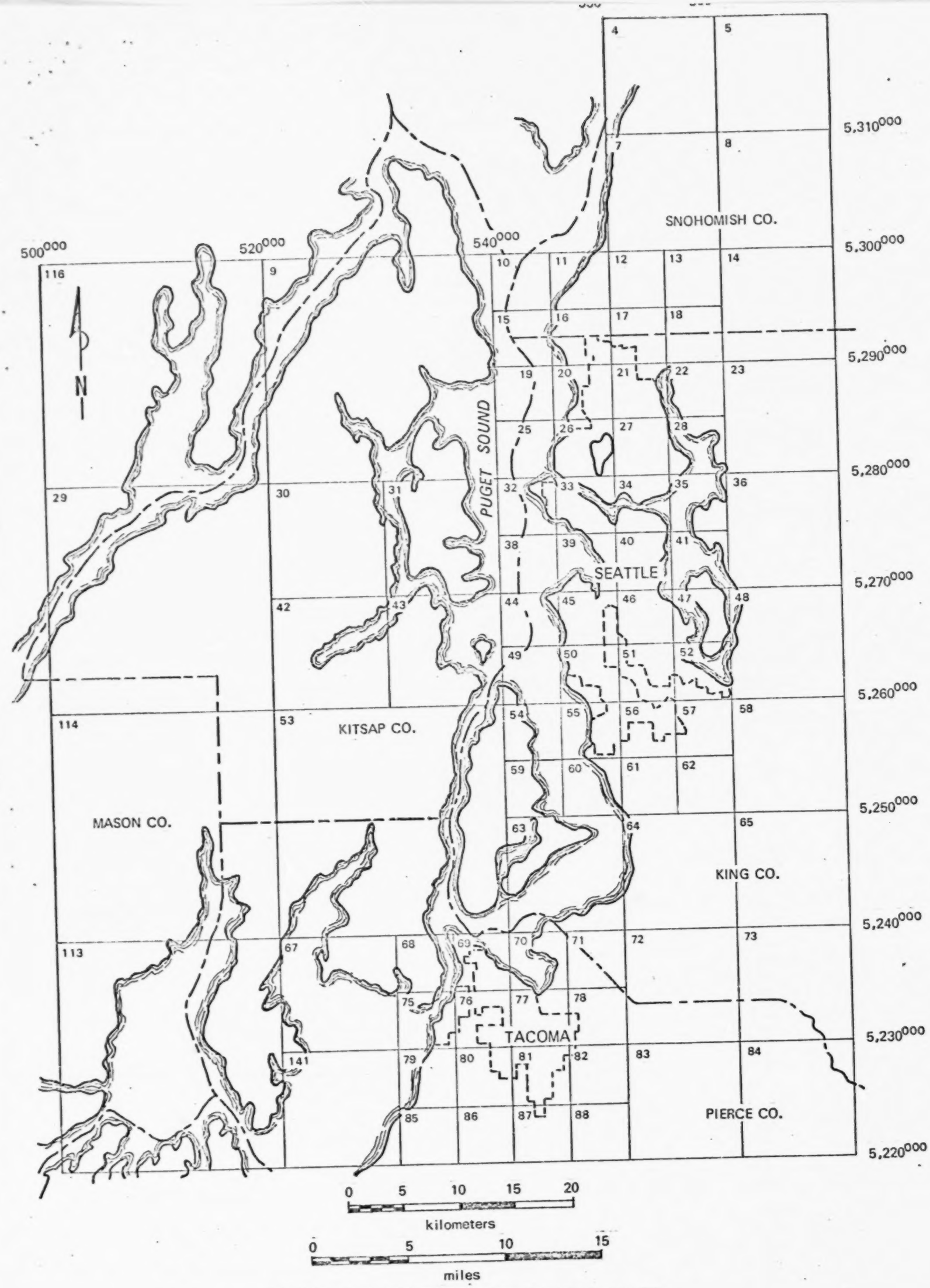


Figure 2A. Seattle - Tacoma metropolitan area.

DISCUSSION OF RESULTS

All the sources of air pollution considered in this survey fall into one of the following four categories:

1. Fuel combustion by stationary sources
2. Transportation sources
3. Refuse disposal
4. Industrial process losses

Each of these categories are considered individually in this section and also in the subsequent section where data sources are given and techniques of calculation are discussed. In addition, the emissions from the point sources are compared with total area emissions.

It is important to note that the estimates presented herein and especially in the process loss category are, in most cases, partial totals. This stems from the unavailability of emission factors as well as appropriate production data. In the case of hydrocarbon emissions where gasoline evaporation was included but solvent evaporation was not, the totals are considerably lower than the actual values. The results should, therefore, be viewed with these limiations in mind.

Fuel Combustion By Stationary Sources:

Tables 4 through 6 present the consumption of fuel oil, natural gas and coal within the Study Area. As shown in these tables, fuel

oil is the primary fuel used in the Area and the use of coal is almost non-existent. During 1967, over 600 million gallons of fuel oil, 48 billion cubic feet of natural gas and 70 thousand tons of coal were burned within the Study Area. In terms of the total energy supplied, fuel oil accounted for about 62 per cent, natural gas for 36 per cent, and coal for approximately 2 per cent. The average chemical characteristics of the fuel are summarized in Table 7.

The industries in the Area are the largest users of fuel. During 1967, they consumed more than 72 per cent of the natural gas and about 33 per cent of the fuel oil burned in the Area. Most of the fuel oil was used by the pulp mills (86 million gallons) and the refineries (58 million gallons), which, for the most part, are located outside the highly populated areas. Much of the industrial use of natural gas is on an interruptable basis requiring the use of fuel oil during some winter periods.

Fuel oil is by far the primary fuel used to provide space heating for homes and apartments. As shown in Table 8, in 1967, more than 77 per cent of the dwelling units were heated by fuel oil. The use of coal is insignificant. The use of natural gas, for domestic heating purposes, has increased significantly during recent years and will undoubtedly continue to do so.

The use of coal is mostly limited to a few of the largest commercial and institutional establishments. During 1967, 70 per cent of the coal was burned in only 5 establishments.

The emissions resulting from the burning of these fuels are summarized in Table 9. The use of fuels is the largest source of sulfur oxides in the Area, except the Tacoma smelter, emitting some 46,000 tons or 18 per cent of the total. Here the largest contributors are industries burning residual fuel oil. In the case of the other pollutants, the combustion of fuels accounts for 25 per cent of particulates, 15 per cent of hydrocarbons, and 20 per cent of the oxides of nitrogen. The use of these fossil fuels is an insignificant source of carbon monoxide emitting less than 0.3 per cent of the total.

Transportation Sources:

In all, four types of transportation sources were considered. These include motor vehicles, aircraft, railroads and vessels. Tables 10 and 11 summarize vehicle mile and gasline-diesel fuel consumption data which were used to calculate the emissions from motor vehicles. About 30 million vehicle miles of travel occur per day within the Study Area, of which about 5 per cent is accounted for by diesel powered vehicles. This rate of travel consumes about 750 million gallons of gasoline and 80 million gallons fo diesel fuel annually.

More than 70 per cent of all travel in the Area occurs in the three urbanized counties of King, Pierce and Snohonish.

There are three major airports located within the Study Area. The air traffic activity at each of these--Seattle-Tacoma, Renton Field and Seattle Boeing Field--is summarized in Tables 12A, 12B, and 12C, respectively. Approximately 370,000 itinerant operations and 294,000 local operations took place during 1967. A local operation is defined as a take-off or landing that originates and ends at the same airport. An itinerant operation is one that either originates or ends at the airport. Air carrier flights are primarily commerical, while general aviation includes all private and pleasure flights.

The other two classes of sources--railroads and vessels--are by comparison minor. During 1967, an estimated 24 million gallons per year of fuel (diesel) were consumed by railroads and approximately 12.5 million gallons were burned by vessels operating within the Study Area.

The emissions from transportation sources are summarized in Table 13. Road vehicles are by far the most significant source of air pollution. In 1967, they accounted for 99 per cent of the carbon monoxide, 96 per cent of the hydrocarbons, 93 per cent of the oxides of nitrogen, 82 per cent of the particulate matter and 65 per cent

of the sulfur oxides (of the total transportation emissions). Diesel fuel powered vehicles were an important source of particulate matter as well as oxides of sulfur.

The emissions from aircraft, although minor, may be significant in that these emissions occur at three locations rather than throughout the Area as is the case for motor vehicle travel. The emissions from vessels and railroad are minor.

Refuse Disposal Sources

The estimated pattern of refuse disposal for the Study Area is summarized in Table 14. More than 50 percent of the refuse is disposed of by sanitary land-fill with the remainder being burned either in incinerators, tepee burners, dumps or by on-site open burning. These are rough estimates and should be considered as such.

The emissions from the burning of refuse are summarized in Table 15. On site open burning is the primary source in this category.

Industrial Process Source

Industrial processes which contribute substantially to the overall emissions are presented in Table 16. The emission estimates are categorized by type of industry.

The largest process emitters in the Area are pulp mills, petroleum refineries and a copper smelter in Tacoma. Pulp mills emit substantial quantities of particulates and sulfur oxides but six of the eleven are the less populous sections of the Study Area. Three of the four refineries emitting sulfur oxides, hydrocarbons, and nitrogen oxides are situated in Skagit and Watcom counties and are removed from the heavily urbanized portion of the Area. Carbon monoxide, which is produced in large quanties in the fluid cracking unit of these refineries, is controled by waste heat boilers. The copper smelter, located about 5 miles from the city of Tacoma, is responsible for over 75% of all the sulfur oxides emitted in the Study Area. The large majority of the smaller industrial establishments contributes appeciably to the total particulate matter when taken collectively, but individually, they may only cause heavy concentrations in the general vicinity of their facilities.

Point Source Emissions vs. Total Emissions

Total point source emissions which included both fuel burning and process information are presented in Table 17. Point sources collectively account for the following percentages of the total pollutants:

Sulfur oxides:	99%
Particulates:	47%
Carbon monoxides:	Negligible
Hydrocarbons:	19%
Nitrogen Oxides:	16%

Table 4. ANNUAL FUEL CONSUMPTION IN POLITCCAL JURISDICTIONS
OF THE SEATTLE-TACOMA STUDY AREA, 1967
Fuel Oil (gal./year)

Jurisdiction	Industrial	Residential	Commercial and Institutional	Total
Clallam County	58,300,000	6,890,000	700,000	65,890,000
Jefferson County	9,954,000	1,520,000	150,000	11,624,000
King County	24,770,000	193,300,000	19,300,000	237,370,000
Kitsap County	100,000	23,470,000	2,300,000	25,870,000
Mason County	Neg.	3,000,000	300,000	3,300,000
Pierce County	55,236,000	49,720,000	4,900,000	109,856,000
Shagit County	19,622,000	11,990,000	1,200,000	32,812,000
Snohomish County	6,867,000	37,190,000	3,700,000	47,757,000
Thurston County	100,000	12,870,000	1,200,000	14,170,000
Whatcom County	40,963,000	14,290,000	1,400,000	56,653,000
Totals	215,912,000	354,240,000	35,150,000	605,302,000

Table 5. ANNUAL FUEL CONSUMPTION IN POLITICAL JURISDICTIONS OF THE SEATTLE-TACOMA STUDY AREA, 1967

Coal (tons/year)

Jurisdiction	Industrial	Residential	Commercial and Institutional	Total
Clallam County	Neg.	110	Neg.	110
Jefferson County	Neg.	60	Neg.	60
King County	500	10,550	12,000	23,050
Kitsap County	Neg.	190	Neg.	190
Mason County	Neg.	200	Neg.	200
Pierce County	600	4,760	26,000	31,360
Skagit County	Neg.	270	Neg.	270
Snohomish County	Neg.	1,940	17,000	18,940
Thurston County	Neg.	220	Neg.	220
Whatcom County	Neg.	3,300	Neg.	3,300
Totals	1,100	21,600	55,000	77,700

Table 6. ANNUAL FUEL CONSUMPTION IN POLITICAL JURISDICTIONS OF THE SEATTLE-TACOMA STUDY AREA, 1967

Gas, million (cubic feet/year)

Jurisdiction	Industrial	Residential	Commercial and Institutional	Total
Clallam County	550	10	10	570
Jefferson County	Neg.	20	10	30
King County	17,600	7,040	3500	28140
Kitsap County	Neg.	120	60	180
Mason County	Neg.	neg	Neg.	Neg.
Pierce County	6,800	3,820	1900	12520
Skagit County	1,800	120	60	1980
Snohomish County	5,300	490	250	6040
Thurston County	1,550	140	70	1760
Whatcom County	950	370	180	1500
Totals	34,550	12,130	6040	52720

Table 7 CHEMICAL ANALYSIS OF FUELS IN
THE SEATTLE-TACOMA STUDY AREA, 1967

Fuel	Sulfur o/o	Ash o/o	Volatile o/o
Coal	0.7	5.0	41.6
Residual Fuel Oil	2.0	N *	---
Distillate Fuel Oil	0.32	N	---
Gas	0.0008	N	---
Hogged Fuel	N.A.**	N.A.	N.A.

* N: Negligible **N.A.: Not Available

TABLE 8 SUMMARY OF DOMESTIC HEATING BY
NUMBER OF DWELLING UNITS IN STUDY AREA, 1967

	All Occupied Units	Coal	Fuel Oil	Utility Gas
Clallam County	8,553	23	8,400	130
Jefferson County	2,117	14	1,850	253
King County	307,943	2,879	235,777	69,287
Kitsap County	30,189	38	28,626	1,525
Mason County	3,828	45	3,662	121
Pierce County	98,909	879	60,642	37,388
Skagit County	15,925	57	14,632	1,236
Snohomish	50,667	366	45,362	4,939
Thurston County	16,923	43	15,700	1,180
Whatcom County	22,608	636	17,436	4,536
Totals	554,425	4,980	432,087	120,595

TABLE 9 AIR POLLUTANT EMISSIONS FROM BURNING OF FUELS BY STATIONARY SOURCES IN SEATTLE-TACOMA STUDY AREA, 1967 (tons/year)

Type Source	Sulfur Oxides	Particulates	Carbon-Monoxide	Hydrocarbons	Nitrogen Oxides
INDUSTRIAL	35,090	5,840	220	23,650	11,660
Natural Gas	Neg.	330	Neg.	Neg.	3,700
Fuel Oil	34,870	2,450	220	220	7,700
Coal	40	30	Neg.	Neg.	10
Hogged Fuel	180	3,030	Neg.	23,430	180
RESIDENTIAL	8,860	1,500	380	530	2,830
Natural Gas	Neg.	100	Neg.	Neg.	700
Fuel Oil	8,880	1,400	350	530	2,130
Coal	20	Neg.	30	Neg.	Neg.
Hogged Fuel	--	--	--	--	--
COMMERCIAL					
Institutional	1,600	820	1,410	330	490
Natural Gas	Neg.	Neg.	Neg.	Neg.	70
Fuel Oil	870	130	30	50	200
Hogged Fuel	Neg.	Neg.	Neg.	Neg.	Neg.
TOTALS	45,570	8,160	2,010	24,510	14,980

TABLE 10 NUMBER OF VEHICLE-MILES TRAVELED IN SEATTLE-TACOMA STUDY AREA BY POLITICAL JURISDICTION

VEH. MILES/DAY

Political Jurisdiction	Gasoline Powered	Diesel Fuel Powered
Clallam County	484,100	25,500
Jefferson County	182,100	8,600
King County	15,497,000	816,000
Kitsap County	861,500	45,300
Mason County	301,900	15,900
Pierce County	4,890,500	257,400
Skagit County	908,300	47,800
Snohomish. County	3,101,800	163,200
Thurston County	1,374,200	72,300
Whatcom County	806,800	42,500
Total	28,498,200	1,494,500

TABLE 11 GASOLINE AND DIESEL FUEL FOR VEHICLES CONSUMED IN STUDY AREA BY POLITICAL JURISDICTION (10^6gal/yr)

Political Jurisdiction	Gasoline		Diesel
	Consumption	Evaporation	Consumption
Clallam County	12.5	0.3	1.4
Jefferson County	4.6	0.1	0.3
King County	409.8	10.2	44.4
Kitsap County	22.8	0.5	2.2
Mason County	7.9	0.2	0.8
Pierce County	129.4	3.3	13.9
Skagit County	23.8	0.6	2.4
Shohomish County	81.8	2.1	8.9
Thurston County	36.3	.9	3.9
Whatcom County	21.2	0.5	2.2
Total Study Area	750.1	18.7	80.4

TABLE 12A AIR TRAFFIC ACTIVITY AT SEATTLE TACOMA INTERNATIONAL
CALENDAR YEAR 1967

	Itinerant Operations	Local Operation
Air Carrier	88,174	------
General Aviation	39,893	12,844
Military	1,587	1,528
Total	129,654	14,372

TABLE 12B AIR TRAFFIC ACTIVITY AT RENTON FIELD
RENTON, WASHINGTON
CALENDAR YEAR 1967

	Itinerant Operations	Local Operation
Air Carrier	2	-------
General Aviation	73,607	111,485
Military	60	83
Total	73,669	111,568

TABLE 12C AIR TRAFFIC ACTIVITY AT SEATTLE BOEING FIELD

SEATTLE, WASHINGTON

CALENDAR YEAR 1967

	Itinerant Operations	Local Operations
Air Carrier	16,441	-------
General Aviation	152,409	167,693
Military	1,476	610
Total	170,326	168,303

TABLE 13 AIR POLLUTANT EMISSIONS FROM TRANSPORTATION SOURCES IN SEATTLE-TACOMA STUDY AREA, 1967 (TONS/YEAR)

	Sulfur Oxides	Particulates	Carbon Monoxides	Hydro carbons	Nitrogen Oxides
Road Vehicles	4,700	8,300	861,500	77,000	51,700
Gasoline	3,200	4,200	859,000	72,000	42,800
Diesel	1,500	4,100	2,500	5,000	8,900
Aircraft	80	420	10,150	1,730	600
Jet	80	380	770	650	320
Piston	Neg.	40	9,380	1,080	280
Railroad	500	1,300	700	1,600	2,700
Vessels	2,000	140	10	10	450
Totals	7,280	10,160	872,360	80,340	55,450

TABLE 14 REFUSE DISPOSAL IN STUDY AREA, 1967 (TONS/YEAR)

Jurisdiction	Total Refuse Generated	Transfer	Incineration On-Site	Landfills	Dumps	Open On-Site Burning	Tepee Burners
Clallam Co.	28,000	---------	------	---------	19,000	5,000	4,000
Jefferson Co.	8,000	---------	------	---------	4,000	2,000	2,000
King Co.	1,339,000	- 350,000	28,000	789,000	3,000	159,000	10,000
Kitsap Co.	79,000	---------	------	---------	19,000	56,000	4,000
Mason Co.	15,000	---------	------	---------	7,000	4,000	4,000
Pierce Co.	438,000	---------	14,000	100,000	18,000	288,000	18,000
Skagit Co.	44,000	---------	------	---------	20,000	10,000	14,000
Snohomish Co.	227,000	+ 350,000	7,000	420,000	3,000	101,000	46,000
Thurston Co.	53,000	---------	------	---------	32,000	17,000	4,000
Whatcom Co.	63,000	---------	------	---------	27,000	22,000	14,000
Total Study Area	2,294,000	---------	49,000	1,309,000	152,000	664,000	120,000

TABLE 15 AIR POLLUTANT EMISSIONS FROM SOLID WASTE DISPOSAL IN SEATTLE-TACOMA STUDY AREA (TONS/YEAR)

	SO_x	PART	CO	HC	NO_x
Total Incineration	49	245	1,078	1	49
Municipal	---	-----	------	-----	-----
On-Site	49	245	1,078	1	49
Total Open Burning	148	5,960	31,663	1,863	4,097
Dumps	18	648	3,443	203	445
On-Site	130	5,312	28,220	1,660	3,652
Tepee Burners	10	156	------	1,200	7
Total Emissions	207	6,361	32,741	3,064	4,153

TABLE 16 INDUSTRIAL EMISSIONS DUE TO PROCESS LOSSES

1967 (tons/year)

Industry Type	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Aluminum Reduction	--	900	--	--	--
Cement Manufacturing	--	2,100	--	--	--
Copper Smelting	196,000	200	--	--	--
Glass Production	--	300	--	--	--
Grain Mills	--	200	--	--	--
Grey Iron Foundry	--	200	--	--	--
Lead Smelting	1,000	100	--	--	--
Lime Production	--	200	--	--	--
Petroleum Refining	30,400	--	--	6,700	1,900
Pulp Mills	3,600	5,500	--	--	--
Steel Mills	--	100	--	--	--
Totals	231,000	9,800	--	6,700	1,900

METHODOLOGY

The following discussion is a summary of the procedures employed in the Seattle-Tacoma emission inventory.

Fuel Combustion by Stationary Sources

The local air pollution agencies were contacted as to the use of fossil fuels in the major industrial and commercial establishments. Approximately 90 major industries and commercial establishments were located and their fuel consumption totaled. This amounted to approximately 150 million gallons of fuel oil, 12 billion cubic feet of natural gas and 60 thousand tons of coal. The large industrial facilities consumed most of the fuel oil and natural gas but only a small portion of the coal. On the basis of this information, 75 per cent of the residual fuel oil and 73 per cent of the coal burned in the area was accounted for by point sources. The balance of the fuel burned in the Seattle-Tacoma Study Area was distributed to the three area source categories of fuel consumption: (1) residential, (2) commercial-institutional, and (3) industry.

The amount of fuel burned for home heating was calculated using the procedure described in the "Rapid Survey Technique". The method includes such variables as total annual and winter degree days, average number of rooms per dwelling unit, and the number of dwelling units using each fuel. It was assumed that all fuel oil burned by residential users was distillate.

Commercial-institutional fuel consumption figures were not available except in the case of natural gas where the gas companies had supplied their annual reports. Natural gas for commercial-institutional was found to be about one half of that sold to residential consumers. Fuel oil consumption was determined by using other reports already completed and was assumed to be distillate. The institutional coal consumption was determined after accounting for the coal consumption by point and residential sources and assuming the commercial usage of coal to be negligible.

After the approximate fuel consumption in the Study Area was determined all point source, residential and commercial-institutional figures were subtracted from the total and the remainder was considered industrial. These fuels, residual fuel oil and natural gas, were distributed to King, Pierce and Snohomish Counties because many moderate sized facilities in these counties were not included in the large fuel user source category.

Transportation Sources

Transportation information was obtained from the following three major sources: (1) a 1966 report on motor vehicle emissions in the City of Seattle by Guntis Ozolins, (2) a traffic flow map of the City of Tacoma, and (3) the 1967 vehicle-miles driven in each county.

The emissions for Seattle were obtained from Ozolins' report by updating the 1966 data with gasoline consumption figures for the State of Washington. These adjusted emissions were then distributed by proportioning the grids used by Ozolins into the larger grids used in this inventory.

The motor vehicles activity for the City of Tacoma was estimated by apportioning the vehicle-miles on the flow map by grid. These vehicle-miles were then multiplied by the appropriate emission factors.

Since the Ozolins' report and flow map included the major commuter traffic for King and Pierce Counties, the remainder of the emissions was distributed in a more general manner. The vehicle-miles of the two cities were subtracted from their county totals and the balance was apportioned into grids by population.

In the other eight counties of the Study Area, flow maps were not available so the vehicle-miles supplied by the State Department of Highways were also apportioned by population.

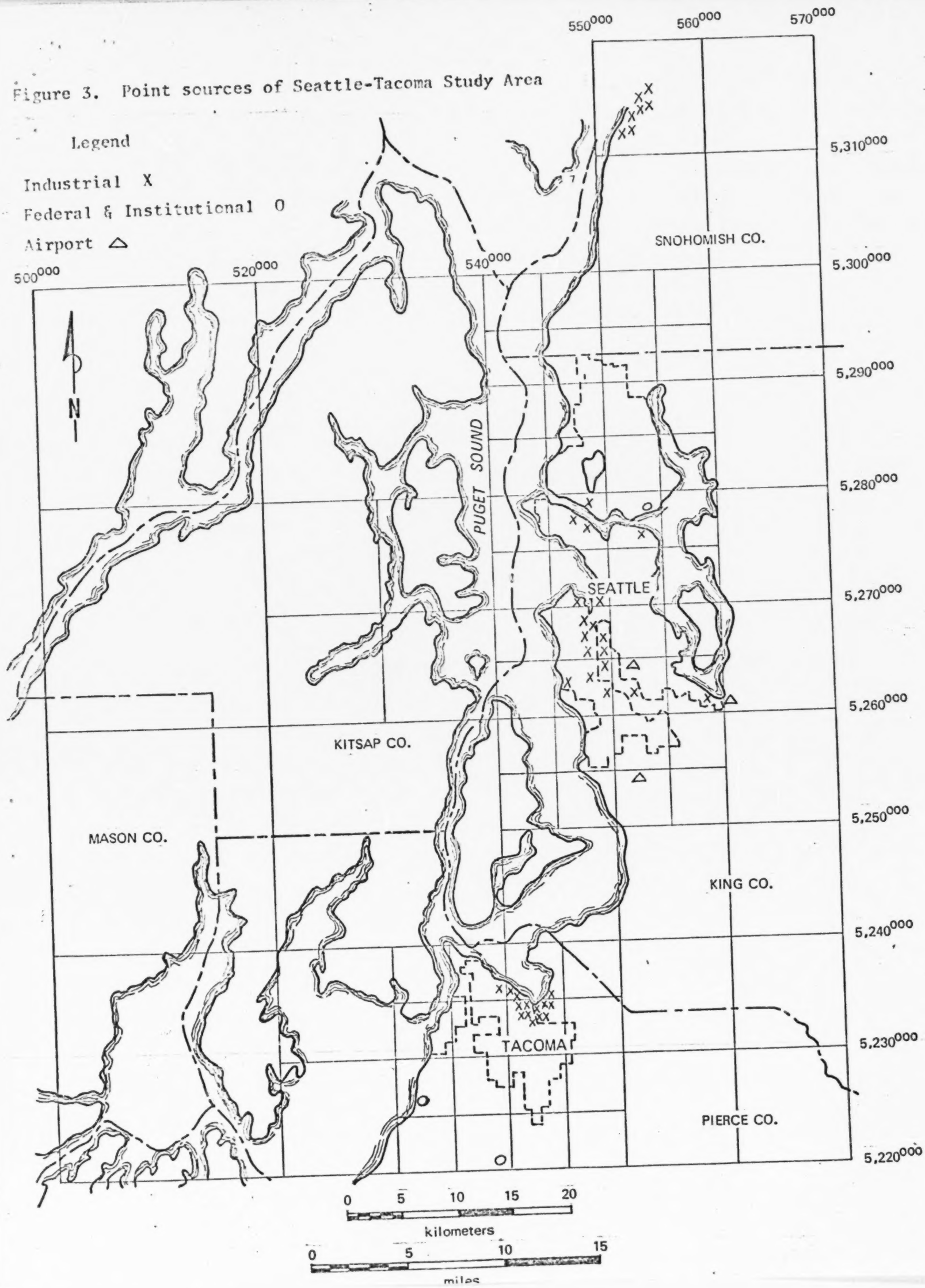
Refuse Disposal Sources

Solid waste disposal information was supplied by the Washington State Department of Health, which had surveyed most the dumps and land fills in the Study Area. With this information, plus the approximate number, size, and location of the tepee burners that handle wood waste, a refuse balance was prepared. Since there were no large incinerators or burning dumps that could be considered point sources, the total refuse emissions were apportioned by population per grid.

Industrial Process Emissions

The information used to estimate the process emissions from point sources was gathered by the acknowledged air pollution agencies. This data was most often in the form of production figures because actual process emissions, for the most part, were not available.

Figure 3. Point sources of Seattle-Tacoma Study Area



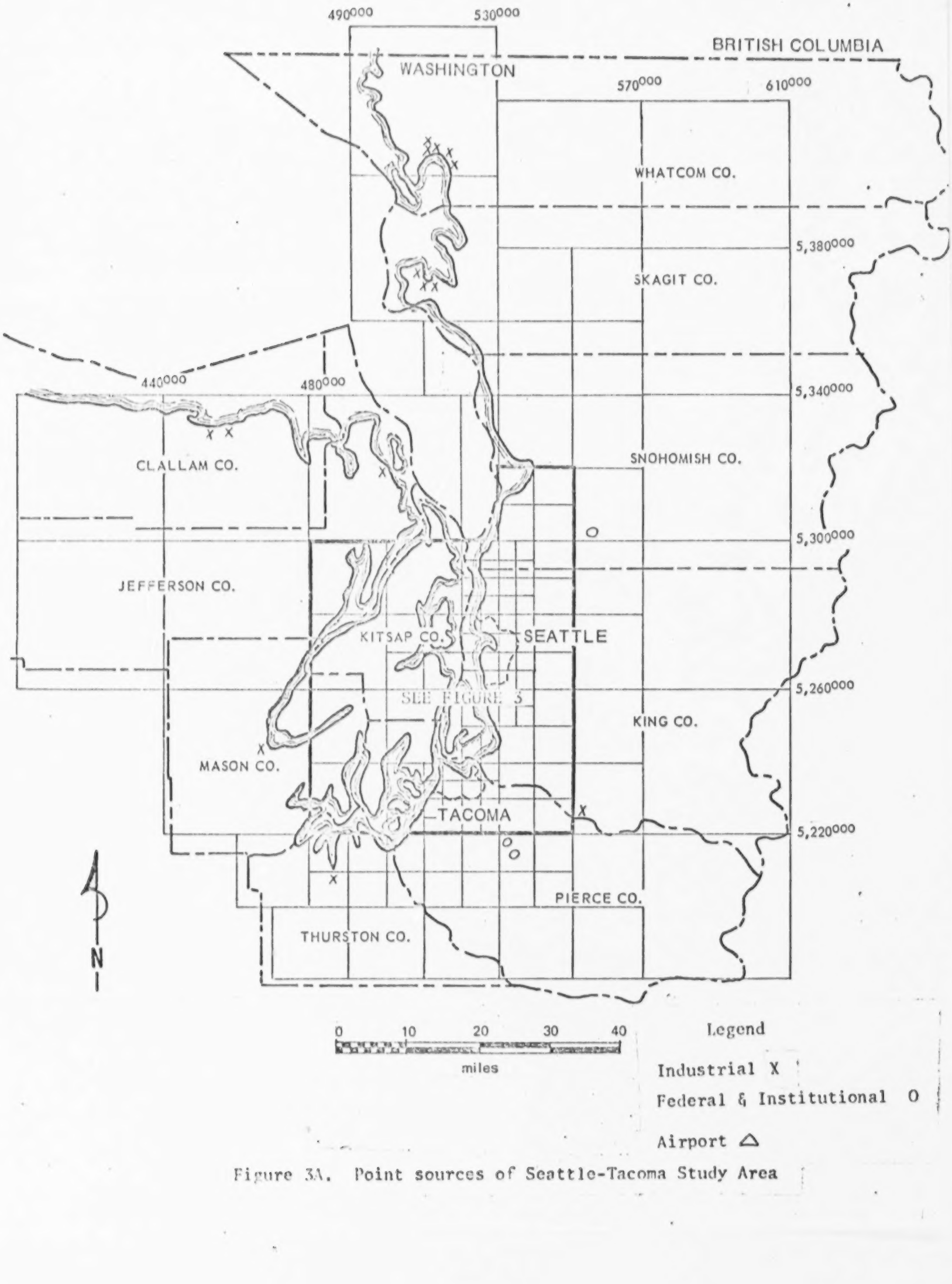


Figure 3A. Point sources of Seattle-Tacoma Study Area

TABLE 17 SUMMARY OF TOTAL EMISSIONS FROM POINT SOURCES

(tons/average day)

Type of Industry	Grid Number	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro Carbon	Nitrogen Oxides
Oil Refineries	77	8.05	.13	.01	1.39	.80
	130	25.51	.58	.05	5.66	1.16
	130	46.98	.80	.12	11.16	2.02
	135	36.81	.49	.04	8.16	1.96
Total		117.35	2.00	.22	26.37	5.94
Grey Iron Foundry	34	--	.27	--	--	--
	45	.01	.01	--	--	.03
	50	--	.01	--	--	--
	52	.04	.19	--	--	.17
	77	--	.02	--	--	--
	78	--	.03	--	--	--
Total		.05	.53	--	--	.20
Chemical	52	.31	.02	--	--	.07
	71	.73	.09	.01	--	.61
	77	.16	.01	--	--	.05
	77	2.74	.20	.02	.02	.62
Total		3.94	.32	.03	.02	1.35

TABLE 17 SUMMARY OF TOTAL EMISSIONS FROM POINT SOURCES (continued)

(tons/average day)

Type of Industry	Grid Number	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-Carbon	Nitrogen Oxides
Woodworking	4	.01	.08	--	.63	--
	4	.02	.25	--	1.91	.01
	4	--	.05	--	.40	--
	4	--	.04	--	.30	--
	33	.02	.38	--	2.90	.01
	33	.02	.39	--	2.96	.02
	33	.01	.10	--	.79	.01
	37	.07	1.14	--	8.76	.05
	74	.03	.50	--	3.83	.02
	76	.04	.69	--	5.37	.03
	78	.01	.19	--	1.45	.01
	78	.08	.10	--	.80	.03
Total		.31	3.91	--	30.10	.19
Breweries	70	.03	.01	--	--	.05
	98	--	.01	--	--	.11
Total		.03	.02	--	--	.16

TABLE 17 SUMMARY OF TOTAL EMISSIONS FROM POINT SOURCES
(tons/average day)

Types of Industry	Grid Number	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-carbon	Nitrogen Oxides
Pulp Mills	4	2.97	.91	--	7.01	.04
	4	.41	2.96	--	--	.25
	4	3.28	.60	.01	3.32	.50
	5	2.23	1.13	.01	.01	.50
	77	6.45	9.58	.04	6.81	1.49
	115	1.04	.12	.01	.01	.37
	119	4.42	3.68	.03	2.83	1.02
	120	12.30	1.08	.07	2.47	2.44
	120	6.35	.74	.03	3.10	1.10
	130	.51	.43	--	3.00	.14
	135	8.46	1.00	.04	4.04	1.53
Total		48.42	22.23	.24	32.60	9.38
Cement Plant	45	--	1.93	--	--	.07
	45	.20	1.57	.01	.01	.28
	50	.11	0.08	--	--	.03
	130	--	0.15	--	--	--
	135	--	0.95	--	--	--
Total		.31	4.68	.01	.01	.38

TABLE 17 SUMMARY OF TOTAL EMISSIONS FROM POINT SOURCES
(tons/average day)

Type of Industry	Grid Number	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-Carbon	Nitrogen Oxides
Aluminum Reduction	78	--	2.50	--	--	--
Total		--	2.50	--	--	--
Lime Production	78	.37	.49	--	--	.08
Total		.37	.49	--	--	.08
Glass Production	51	.29	.87	--	--	.07
Total		.29	.87	--	--	.07
Steam Production	39	1.83	.13	.01	.01	.41
	77	1.73	0.13	.01	.01	.39
Total		3.56	.26	.02	.02	.80
Mineral Products	78	--	0.19	--	--	--
Alloy Products	78	--	0.64	--	--	--
Total		--	0.83	--	--	--
Copper Smelting	69	587.5	.83	.02	.03	1.03
Total		587.5	.83	.02	.03	1.03

TABLE 17 SUMMARY OF TOTAL EMISSIONS FROM POINT SOURCES
(tons/average day)

Type of Industry	Grid Number	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-Carbon	Nitrogen Oxides
Lead Smelting	45	2.54	.22	--	--	.01
	51	.33	.03	--	--	--
Total		2.87	.25	--	--	.01
Steel Mills	33	.02	.03	--	--	.13
	45	--	.20	--	--	--
	46	--	.10	--	--	.30
	77	.02	.86	1.02	--	10.03
Total		.04	1.19	1.02	--	10.46
Feed and Grain Mills	39	--	.30	--	--	--
	39	--	.33	--	--	--
	78	--	.10	--	--	--
Total		--	.73	--	--	--
Food Products	77	.82	.06	--	--	.18
Total		.82	.06	--	--	.18

TABLE 17 SUMMARY OF TOTAL EMISSIONS FROM POINT SOURCES
(tons/average day)

Type of Industry	Grid Number	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-carbon	Nitrogen Oxides
Institutions	6	.18	.17	.34	.07	.05
	34	.89	.84	1.67	.33	.28
	79	.18	.17	.34	.07	.05
	95	.59	.56	1.11	.22	.18
Total		1.84	1.74	3.46	.69	0.56
Commercial	85	.27	.18	--	1.20	.07
Total		.27	.18	--	1.20	.07
Federal Facilities	93	2.19	.24	.02	.02	.77
	130	2.80	.31	.02	.02	.99
Total		4.99	.55	.04	.04	1.76
Grand Totals		772.96	44.17	4.06	91.08	32.62

SEATTLE - TACOMA

TABLE 18

SUMMARY OF AREA SOURCE EMISSIONS BY SEASON FOR THE STUDY AREA, 1967 (TONS/DAY)

Grid	Horizontal Coordinate (100m)	Vertical Coordinate (100m)	Area (Km^2)	SO_x Sum.	SO_x Win.	SO_x Avg.	PART Sum.	PART Win.	PART Avg.	CO Sum.	CO Win.	CO Avg.
1	5600	53300	400	.11	.12	.11	.20	.31	.31	21.89	19.66	20.89
2	5800	53300	400	.03	.03	.03	.07	.07	.07	5.61	5.03	5.35
3	6100	53200	1600	.04	.17	.11	.10	.12	.11	7.54	6.77	7.19
4	5550	53150	100	.04	.52	.38	.25	.29	.26	3.84	3.61	3.74
5	5650	53150	100	.11	.52	.46	.46	.56	.52	4.55	4.21	4.41
6	5800	53100	400	.08	.09	.08	.23	.22	.23	15.89	14.26	15.16
7	5550	53050	100	.23	.27	.25	.63	.66	.65	42.04	37.73	40.12
8	5650	53050	100	.08	.10	.09	.22	.24	.23	15.36	13.83	14.67
9	5300	52900	400	.07	.51	.31	.24	.30	.19	12.34	11.13	11.80
10	5425	52975	25	.36	.36	.36	.03	.03	.03	0.00	0.00	0.00
11	5475	52975	25	.04	.05	.05	.10	.11	.11	8.72	7.83	8.32
12	5525	52975	25	.05	.06	.06	.15	.14	.15	10.89	9.78	10.40
13	5575	52975	25	.03	.04	.03	.07	.06	.07	5.48	5.56	5.54
14	5650	52950	100	.08	.13	.06	.14	.15	.14	13.86	12.85	13.40
15	5425	52925	25	.36	.36	.36	.03	.03	.03	0.00	0.00	0.00
16	5475	52925	25	.24	.84	.31	.63	.71	.63	49.26	44.65	47.19
17	5525	52925	25	.17	.53	.20	.43	.48	.43	30.75	27.62	29.34
18	5575	52925	25	.05	.18	.06	.11	.13	.11	12.38	11.42	11.95
19	5425	52875	25	.36	.36	.36	.03	.03	.03	0.00	0.00	0.00

SEATTLE - TACOMA

TABLE 18

SUMMARY OF AREA SOURCE EMISSIONS BY SEASON FOR THE STUDY AREA, 1967 (TONS/DAY)

Grid	Horizontal Coordinate (100m)	Vertical Coordinate (100m)	Area (Km^2)	SO_x Sum.	SO_x Win.	SO_x Avg.	PART Sum.	PART Win.	PART Avg.	CO Sum.	CO Win.	CO Avg.
20	5475	52875	25	.45	1.13	.61	.40	.50	.42	35.30	33.14	34.87
21	5525	52875	25	.59	1.88	.84	.76	.79	.79	60.79	55.15	58.22
22	5575	52875	25	.06	.37	.09	.15	.20	.15	16.26	15.11	15.74
23	5650	52850	100	.08	.48	.13	.22	.27	.22	20.84	19.12	20.07
24	5800	52900	400	.03	.04	.03	.06	.10	.09	.24	7.05	6.33
25	5425	52825	25	.36	.44	.41	.06	.08	.07	1.45	1.44	1.44
26	5475	52825	25	.62	2.41	1.68	1.13	1.41	1.29	59.62	54.11	57.17
27	5525	52825	25	.40	2.39	1.68	1.09	1.37	1.24	54.67	49.69	52.46
28	5575	52825	25	.10	.54	.19	.27	.35	.28	29.24	26.77	28.13
29	5100	52700	400	.01	.08	.05	.04	.04	.03	1.90	1.71	1.82
30	5250	52750	100	.06	.40	.25	.19	.24	.22	20.26	19.25	19.82
31	5350	52750	100	.39	.59	.51	.15	.17	.17	5.91	5.34	5.65
32	5425	52775	25	.38	.63	.51	.15	.21	.18	5.74	5.54	5.65
33	5475	52775	25	.71	2.73	1.89	1.39	1.70	1.54	75.63	68.54	72.48
34	5525	52775	25	.58	2.45	1.67	1.02	1.38	1.24	45.18	40.70	43.19
35	5575	52775	25	.11	.74	.20	.29	.43	.31	25.37	23.36	24.40
36	5650	52750	100	.17	.98	.25	.43	.54	.43	38.02	34.89	36.09
37	5800	52700	400	.09	.50	.13	.22	.27	.22	21.84	20.12	21.07

SEATTLE - TACOMA

TABLE 18

SUMMARY OF AREA SOURCE EMISSIONS BY SEASON FOR THE STUDY AREA, 1967 (TONS/DAY)

Grid	Horizontal Coordinate (100m)	Vertical Coordinate (100m)	Area (Km^2)	SO_x Sum.	SO_x Win.	SO_x Avg.	PART Sum.	PART Win.	PART Avg.	CO Sum.	CO Win.	CO Avg.
38	5425	52725	25	.73	.73	.73	.05	.05	.05	0.00	0.00	0.00
39	5475	52725	25	1.11	1.47	1.34	.88	.93	.94	78.91	70.78	75.28
40	5525	52725	25	.83	2.84	2.91	1.94	2.21	2.09	66.13	59.30	63.08
41	5575	52725	25	.17	1.47	.57	.41	.64	.44	35.93	32.98	34.54
42	5250	52650	100	.19	1.38	.85	.70	.87	.79	22.88	22.29	22.40
43	5350	52650	100	.01	.22	.13	.09	.12	.11	2.78	2.53	2.66
44	5425	52675	25	.37	.52	.45	.10	.12	.11	2.19	2.01	2.11
45	5475	52675	25	1.40	2.78	2.24	1.14	1.29	1.23	56.83	50.04	54.25
46	5525	52675	25	1.16	2.34	1.93	1.52	1.63	1.60	57.57	51.77	54.99
47	5575	52675	25	.14	.78	.28	.36	.49	.38	29.85	26.93	28.50
48	5650	52650	100	.19	1.14	.28	.49	.63	.50	42.67	38.90	40.93
49	5425	52625	25	.73	.73	.73	.05	.05	.05	0.00	0.00	0.00
50	5475	52625	25	1.19	3.25	2.39	.85	1.14	.93	43.26	38.52	40.61
51	5525	52625	25	1.09	1.97	1.31	1.45	1.64	1.50	64.21	59.80	62.19
52	5575	52625	25	.15	1.00	.24	.49	.67	.54	42.32	39.56	40.09
53	5300	52500	400	.10	.46	.22	.39	.38	.39	15.42	16.62	17.61
54	5425	52575	25	0.00	0.03	0.00	.01	.01	.01	1.96	1.86	1.91
55	5475	52575	25	.18	1.14	.28	.46	.68	.46	38.77	35.54	37.24

SEATTLE - TACOMA

TABLE 18

SUMMARY OF AREA SOURCE EMISSIONS BY SEASON FOR THE STUDY AREA, 1967 (TONS/DAY)

Grid	Horizontal Coordinate (100m)	Vertical Coordinate (100m)	Area (Km^2)	SO_x Sum.	SO_x Win.	SO_x Avg.	PART Sum.	PART Win.	PART Avg.	CO Sum.	CO Win.	CO Avg.
56	5525	52575	25	.61	2.17	.77	.77	1.12	.79	61.29	54.90	58.75
57	5575	52575	25	.17	.65	.21	.42	.39	.42	24.78	22.75	23.76
58	5650	52550	100	.18	1.11	.27	.47	.61	.47	38.86	35.44	37.31
59	5425	52525	25	.00	.03	.00	.01	.01	.01	1.96	1.87	1.91
60	5475	52525	25	.06	.33	.08	.15	.19	.15	15.26	14.11	14.74
61	5525	52525	25	.36	1.30	.45	1.28	1.41	1.32	42.48	41.22	41.85
62	5575	52525	25	.12	.50	.22	.33	.39	.35	17.12	16.89	17.56
63	5450	52450	100	.05	.30	.08	.12	.16	.12	19.99	18.97	19.52
64	5550	52450	100	.26	1.21	.35	.67	.81	.68	37.80	33.98	36.07
65	5650	52450	100	.07	.44	.10	.17	.23	.17	18.32	16.96	17.70
66	5800	52500	400	.10	.62	.16	.27	.34	.27	25.12	23.07	24.19
67	5250	52350	100	.02	.07	.04	.05	.05	.04	3.11	2.79	2.97
68	5325	52375	25	.00	.01	.00	.00	.00	.00	.16	.15	.16
69	5375	52375	25	.28	.56	.43	.20	.26	.23	7.83	7.12	7.52
70	5425	52375	25	.02	.09	.06	.07	.09	.08	4.19	3.79	4.01
71	5475	52375	25	.05	.24	.08	.12	.15	.13	20.32	19.26	19.84
72	5550	52350	100	.26	1.02	.33	.70	.80	.70	38.46	36.73	36.71
73	5650	52350	100	.06	.30	.08	.15	.19	.15	14.45	13.29	13.92

SEATTLE - TACOMA

TABLE 18

SUMMARY OF AREA SOURCE EMISSIONS BY SEASON FOR THE STUDY AREA, 1967 (TONS/DAY)

Grid	Horizontal Coordinate (100m)	Vertical Coordinate (100m)	Area (Km^2)	SO_x Sum.	SO_x Win.	SO_x Avg.	PART Sum.	PART Win.	PART Avg.	CO Sum.	CO Win.	CO Avg.
74	5800	52300	400	.09	.51	.14	.25	.31	.25	23.30	21.44	22.47
75	5325	52325	25	.29	.31	.30	.53	.50	.53	65.67	59.87	63.07
76	5375	52325	25	.36	1.02	.73	.48	.61	.56	23.61	21.28	22.58
77	5425	52325	25	.56	1.91	1.41	1.18	1.39	1.32	34.42	31.10	32.95
78	5475	52325	25	.57	.65	.62	.63	.65	.64	5.95	5.41	5.70
79	5325	52275	25	.01	.01	.01	.07	.08	.08	3.02	2.73	2.89
80	5375	52275	25	.08	.39	.26	.29	.36	.33	14.85	13.46	14.24
81	5425	52275	25	.52	1.90	1.37	.58	.81	.71	14.85	19.41	20.52
82	5475	52275	25	.09	.22	.17	.29	.33	.32	6.08	5.53	5.82
83	5550	52250	100	.28	.26	.27	.77	.77	.77	41.46	37.14	39.53
84	5650	52250	100	.04	.05	.03	.09	.10	.10	12.35	11.60	12.01
85	5325	52225	25	.10	.09	.09	.28	.27	.28	19.77	17.75	18.86
86	5375	52225	25	.15	.14	.14	.41	.40	.40	28.29	25.40	26.99
87	5425	52225	25	.13	.23	.19	.34	.36	.35	25.10	22.54	23.95
88	5475	52225	25	.07	.06	.07	.19	.19	.20	14.09	12.65	13.45
89	4900	52100	400	.05	.05	.04	.08	.07	.07	8.82	7.89	8.40
90	5050	52150	100	.14	.16	.15	.35	.34	.35	27.07	24.30	22.83
91	5150	52150	100	.06	.05	.06	.16	.15	.16	12.08	10.84	11.53
92	5250	52150	100	.05	.04	.04	.13	.03	.14	9.55	8.58	9.12

SEATTLE - TACOMA

TABLE 18

SUMMARY OF AREA SOURCE EMISSIONS BY SEASON FOR THE STUDY AREA, 1967 (TONS/DAY)

Grid	Horizontal Coordinate (100m)	Vertical Coordinate (100m)	Area (Km^2)	SO_x Sum.	SO_x Win.	SO_x Avg.	PART Sum.	PART Win.	PART Avg.	CO Sum.	CO Win.	CO Avg.
93	5350	52150	100	.13	.12	.13	.36	.36	.36	25.44	22.85	24.28
94	5450	52150	100	.11	.11	.11	.32	.32	.32	22.60	20.30	21.57
95	5550	52150	100	.02	.15	.12	.06	.17	.14	4.54	4.14	4.34
96	5650	52150	100	.00	.00	.00	.01	.00	.00	.67	.61	.65
97	5800	52100	400	.01	.00	.00	.01	.01	.01	1.26	1.13	1.20
98	5050	52050	100	.21	.23	.22	.51	.50	.51	39.16	35.14	37.17
99	5150	52050	100	.08	.09	.08	.19	.18	.19	15.49	13.89	14.77
100	5250	52050	100	.05	.06	.05	.14	.14	.15	10.73	9.64	10.24
101	5350	52050	100	.04	.04	.04	.10	.10	.10	7.98	7.16	7.61
102	5450	52050	100	.03	.02	.03	.07	.06	.07	5.56	4.98	5.30
103	5550	52050	100	.01	.01	.01	.01	.01	.01	1.67	1.50	1.59
104	5650	52050	100	.00	.00	.00	.01	.00	.00	.66	.59	.63
105	5000	51900	400	.03	.04	.03	.08	.07	.07	6.35	5.70	6.06
106	5200	51900	400	.04	.04	.04	.09	.08	.08	7.86	7.05	7.50
107	5400	51900	400	.03	.03	.03	.08	.07	.07	6.46	5.79	6.10
108	5600	51900	400	.02	.07	.04	.05	.05	.05	3.19	2.87	3.05
109	5800	51900	400	.01	.01	.03	.01	.02	.01	1.67	1.50	1.59
110	6100	52000	1600	.00	.02	.01	.01	.01	.01	1.82	1.74	1.78

SEATTLE - TACOMA

TABLE 18

SUMMARY OF AREA SOURCE EMISSIONS BY SEASON FOR THE STUDY AREA, 1967 (TONS/DAY)

Grid	Horizontal Coordinate (100m)	Vertical Coordinate (100m)	Area (Km^2)	SO_x Sum.	SO_x Win.	SO_x Avg.	PART Sum.	PART Win.	PART Avg.	CO Sum.	CO Win.	CO Avg.
111	6100	52400	1600	.02	.18	.04	.06	.07	.06	8.57	8.11	8.36
112	6100	52800	1600	.04	.29	.09	.10	.13	.11	10.23	9.39	9.85
113	5100	52300	400	.03	.02	.02	.06	.06	.06	5.06	4.54	4.84
114	5100	52500	400	.02	.05	.04	.05	.05	.05	3.58	3.21	3.41
115	4800	52400	1600	.11	.12	.11	.28	.28	.28	21.32	19.16	20.35
116	5100	52900	400	.01	.01	.01	.02	.02	.02	2.39	2.14	2.28
117	4800	52800	1600	.01	.01	.01	.01	.01	.01	1.21	1.08	1.15
118	4400	52800	1600	.00	.01	.00	.00	.00	.00	.05	.05	.05
119	5200	53200	1600	.07	.10	.08	.17	.18	.17	13.48	12.14	12.86
120	4800	53200	1600	.22	.98	.70	.57	.65	.62	37.17	33.33	35.45
121	4400	53200	1600	.02	.10	.07	.06	.06	.06	4.46	4.00	4.25
123	5400	53500	400	.07	.06	.06	.19	.23	.21	14.01	12.58	13.37
124	5600	53500	400	.05	.06	.05	.14	.16	.16	10.52	9.44	10.03
125	5800	53500	400	.03	.14	.09	.08	.10	.09	5.92	5.32	5.65
128	5600	53700	400	.05	.55	.33	.24	.33	.29	9.14	8.32	8.77
129	5800	53700	400	.04	.18	.12	.10	.13	.12	8.42	7.56	8.03
130	5300	53800	1600	.20	1.13	.66	.57	.72	.65	34.65	31.14	33.06
133	5700	54000	1600	.00	.10	.06	.02	.03	.03	.09	.09	.09

SEATTLE - TACOMA

TABLE 18

SUMMARY OF AREA SOURCE EMISSIONS BY SEASON FOR THE STUDY AREA, 1967 (TONS/DAY)

Grid	Horizontal Coordinate (100m)	Vertical Coordinate (100m)	Area (Km^2)	SO_x Sum.	SO_x Win.	SO_x Avg.	PART Sum.	PART Win.	PART Avg.	CO Sum.	CO Win.	CO Avg.
135	5300	54200	1600	.29	1.95	.22	.94	1.29	1.14	50.45	45.59	48.31
139	6100	54000	1600	.01	.08	.05	.04	.05	.04	2.12	1.91	2.03
140	6100	53600	1600	.03	.12	.08	.07	.07	.07	5.42	4.86	5.07
141	5250	52250	100	.03	.12	.08	.07	.07	.07	5.34	4.79	5.09

Table 18 continued

Grid	HC Sum.	HC Win.	HC Avg.	NO_x Sum.	NO_x Win.	NO_x Avg.
1	4.32	4.13	4.23	1.37	1.34	1.37
2	.76	.77	.72	.44	.37	.33
3	1.13	1.06	1.10	.46	.45	.46
4	.57	.55	.55	.31	.54	.46
5	1.01	1.02	.99	.78	1.07	.97
6	3.32	3.18	3.26	.99	.98	.99
7	7.58	7.22	7.42	2.69	2.65	2.70
8	2.27	2.15	2.21	.95	.95	.96
9	1.73	1.65	1.69	.79	.82	.81
10	0.00	0.00	0.00	0.00	0.00	0.00
11	1.33	1.25	1.27	.54	.49	.54
12	1.71	1.52	1.57	.68	.67	.68
13	.43	.41	.45	.35	.34	.35
14	1.52	1.44	1.48	.61	.61	.61
15	0.00	0.00	0.00	0.00	0.00	0.00
16	7.76	7.41	7.58	2.81	2.84	2.76
17	5.56	5.32	5.44	1.91	1.93	1.88
18	1.38	1.31	1.34	.57	.58	.56
19	0.00	0.00	0.00	0.00	0.00	0.00

Table 18 continued

Grid	HC Sum.	HC Win.	HC Avg.	NO_x Sum.	NO_x Win.	NO_x Avg.
20	5.52	5.30	5.42	1.88	1.90	1.83
21	9.11	8.85	8.92	3.40	3.50	3.34
22	1.74	1.65	1.69	.69	.73	.68
23	3.39	3.28	3.34	1.04	1.06	1.00
24	1.16	1.03	1.06	.43	.46	.42
25	.04	.04	.04	.04	.06	.05
26	9.31	8.95	9.16	3.72	3.78	3.77
27	8.40	8.08	8.27	3.41	3.64	3.59
28	4.94	4.73	4.90	1.42	1.41	1.33
29	.31	.29	.30	.12	.13	.12
30	1.35	1.30	1.32	.74	.68	.67
31	.79	.76	.78	.38	.40	.39
32	.43	.43	.43	.20	.27	.23
33	12.26	11.61	11.94	4.73	4.89	4.87
34	8.03	7.75	7.92	4.16	4.43	1.35
35	4.09	3.97	4.02	1.26	1.35	1.23
36	5.58	5.36	5.46	1.91	2.00	1.86
37	3.39	3.28	3.34	1.04	1.06	1.00
38	0.00	0.00	0.00	0.00	0.00	0.00

Table 18 continued

Grid	HC Sum.	HC Win.	HC Avg.	NO_x Sum.	NO_x Win.	NO_x Avg.
39	13.53	12.89	13.25	4.43	4.80	4.64
40	12.36	11.91	12.18	5.34	5.56	4.49
41	5.57	5.39	5.46	1.90	2.10	1.93
42	.59	.65	.63	.41	.70	.58
43	.39	.39	.39	.17	.21	.18
44	.39	.39	.38	.15	.18	.17
45	11.11	11.69	11.93	4.84	4.95	4.91
46	11.50	11.08	11.31	5.49	5.57	5.52
47	4.38	4.20	4.28	1.73	1.76	1.68
48	6.53	6.28	6.62	2.26	2.36	2.19
49	0.00	0.00	0.00	0.00	0.00	0.00
50	6.67	6.47	6.57	4.13	4.36	4.19
51	10.90	10.61	10.74	7.84	7.97	7.90
52	4.08	3.92	3.99	2.51	2.62	2.53
53	2.54	2.39	2.47	1.19	1.08	1.14
54	.08	.07	.07	.06	.05	.05
55	5.81	5.61	5.69	2.08	2.19	2.02
56	10.69	10.35	10.47	3.49	3.66	3.39
57	2.84	2.70	2.76	1.56	1.60	1.58

Table 18 continued

Grid	HC Sum.	HC Win.	HC Avg.	NO_x Sum.	NO_x Win.	NO_x Avg.
58	5.80	5.54	5.68	2.10	2.20	2.03
59	.08	.07	.07	.06	.06	.05
60	1.54	1.45	1.48	.64	.72	.67
61	6.71	6.45	6.58	3.58	3.61	3.59
62	2.21	2.12	2.17	1.09	1.14	1.07
63	1.83	1.76	1.79	.61	.64	.59
64	6.33	6.07	6.20	2.68	1.76	2.60
65	2.11	2.01	2.06	.81	.85	.79
66	2.67	2.52	2.59	1.24	1.29	1.20
67	.46	.43	.45	.19	.19	.18
68	.01	.01	.01	.01	.01	.01
69	1.15	1.11	1.14	.52	.59	.56
70	.65	.62	.63	.26	.27	.27
71	1.46	1.38	1.42	.63	.63	.62
72	6.36	6.11	6.25	2.63	2.78	2.67
73	1.45	1.37	1.41	.71	.73	.69
74	2.52	2.39	2.45	1.13	1.17	1.10
75	9.61	9.13	9.39	3.35	3.04	3.21
76	3.65	3.90	3.99	1.58	1.65	1.64

Table 18 continued

Grid	HC Sum.	HC Win.	HC Avg.	NO_x Sum.	NO_x Win.	NO_x Avg.
77	7.07	6.85	6.98	3.29	3.46	3.43
78	1.50	1.47	1.49	1.52	1.52	1.52
79	.46	.43	.44	.70	.24	.23
80	2.24	2.15	2.19	.95	1.00	.96
81	4.25	4.17	4.23	1.60	1.89	1.80
82	1.11	1.08	1.09	.73	.75	.75
83	7.73	7.37	7.51	.81	.81	.81
84	.61	.55	.58	1.23	1.22	1.24
85	1.64	1.47	1.56	1.23	1.22	1.24
86	2.35	2.11	2.24	1.77	1.75	1.77
87	2.08	1.88	1.99	1.56	1.52	1.55
88	1.17	1.05	1.11	.87	.86	.87
89	.73	.65	.67	.53	.48	.50
90	2.24	2.01	2.14	1.67	1.60	1.65
91	1.01	.90	.96	.75	.77	.77
92	.80	.72	.76	.60	.59	.59
93	2.11	1.90	2.02	1.59	1.57	1.59
94	1.88	1.69	1.79	1.41	1.39	1.42
95	.36	.37	.36	.26	.31	.30

Table 18 continued

Grid	HC Sum.	HC Win.	HC Avg.	NO_x Sum.	NO_x Win.	NO_x Avg.
96	.06	.05	.05	.04	.04	.04
97	.10	.09	.10	.08	.08	.07
98	3.21	2.92	3.10	2.42	2.32	2.39
99	1.29	1.16	1.23	.95	.92	.94
100	.80	.80	.80	.67	.65	.67
101	.67	.60	.63	.50	.50	.50
102	.46	.41	.44	.34	.33	.34
103	.14	.13	.13	.10	.10	.10
104	.05	.05	.05	.04	.04	.04
105	1.03	.97	1.00	.39	.37	.39
106	1.15	1.08	1.12	.48	.46	.47
107	1.04	.98	1.01	.39	.38	.39
108	.47	.44	.45	.20	.20	.20
109	. 27	.22	.23	.10	.10	.10
110	.07	.06	.06	.05	.04	.05
111	.68	.65	.66	.28	.29	.27
112	1.19	1.12	1.15	.50	.51	.49
113	.72	.68	.70	.31	.30	.31
114	.55	. 52	.53	.22	.22	.22

Table 18 continued

Grid	HC Sum.	HC Win.	HC Avg.	NO_x Sum.	NO_x Win.	NO_x Avg.
115	4.27	4.09	4.18	1.31	1.26	1.30
116	.40	.38	.39	.14	.14	.13
117	.10	.09	.09	.09	.07	.06
118	.00	.00	.00	.00	.00	.00
119	3.12	3.07	3.09	.83	.79	.80
120	6.67	6.39	5.55	2.37	2.30	2.36
121	.67	.63	.65	.27	.26	.27
123	1.16	1.04	1.10	.89	1.09	1.01
124	1.68	1.58	1.63	.66	.72	.70
125	.79	.74	.77	.36	.36	.37
128	1.36	1.33	1.35	.60	.67	.65
129	1.30	1.23	1.27	.51	.50	.51
130	7.46	7.23	7.36	2.23	2.22	2.24
133	.01	.01	.01	.01	.04	.02
135	9.87	9.60	9.76	3.32	3.41	3.41
139	. 38	.36	.37	.13	.14	.13
140	. 85	.80	.83	.33	.32	.32
141	.84	.80	.83	.32	.32	.32

TABLE 19 TOTAL EMISSIONS BY GRID FOR SEATTLE-TACOMA STUDY AREA
(Tons/Average Day)

Grid Number	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-Carbon	Nitrogen Oxides
1	0.11	0.31	20.89	4.23	1.37
2	0.03	0.07	5.35	0.72	0.33
3	0.11	0.11	7.19	1.10	0.46
4	7.08	5.16	3.74	14.12	1.28
5	3.66	0.68	24.42	1.00	1.46
6	0.26	0.40	15.50	3.33	1.04
7	0.25	0.65	40.12	7.42	2.70
8	0.09	0.23	14.67	2.21	0.96
9	0.31	0.19	11.80	1.69	0.81
10	0.36	0.03	--	--	--
11	0.05	0.11	8.32	1.27	0.54
12	0.06	0.15	10.40	1.57	0.68
13	0.03	0.07	0.56	0.45	0.35
14	0.06	0.14	13.40	1.48	0.61
15	0.36	0.03	--	--	--
16	0.31	0.63	47.19	7.58	2.76
17	0.20	0.43	29.34	5.45	1.88
18	0.06	0.11	11.95	1.34	0.56
19	0.36	0.03	--	--	--
20	0.61	0.42	34.87	5.42	1.83
21	0.84	0.79	58.22	8.92	3.34
22	0.09	0.15	15.74	1.69	0.68
23	0.13	0.20	20.07	3.34	1.00
24	0.03	0.09	6.33	1.06	0.42
25	0.41	0.07	1.44	0.04	0.05
26	1.68	1.29	57.17	9.16	3.77
27	1.68	1.24	52.46	8.27	3.59
28	.19	.28	28.13	4.90	3.59

TABLE 19 TOTAL EMISSIONS BY GRID FOR SEATTLE TACOMA STUDY AREA
(Tons/Average Day)

Grid Number	Sulfur Oxides	Particulates	Carbon Monoxides	Hydro-carbon	Nitrogen Oxides
29	.05	.03	1.82	.30	.12
30	.25	.22	19.82	1.32	.67
31	.51	.17	5.65	.78	.39
32	.51	.18	5.65	.43	.23
33	1.96	2.30	72.48	17.80	5.04
34	2.24	8.03	44.86	1.57	1.95
35	.20	.31	24.40	4.02	1.23
36	.25	.43	36.09	5.46	1.86
37	.20	1.36	21.07	12.10	1.05
38	.73	.05	--	--	--
39	3.17	1.70	75.29	13.26	5.05
40	2.41	2.09	63.08	12.18	4.64
41	.57	.44	34.54	5.46	4.49
42	.85	.79	22.40	.63	1.93
43	.13	.11	2.66	.39	.58
44	.45	.11	2.11	.38	.18
45	5.08	5.17	54.26	11.94	5.05
46	1.93	1.71	54.99	11.31	5.82
47	.28	.38	28.50	4.28	5.52
48	.28	.50	40.93	6.62	2.19
49	.73	.05	--	--	--
50	2.56	1.03	40.61	6.57	4.23
51	1.92	2.40	62.19	10.74	7.90
52	.45	.75	40.09	3.99	2.78
53	.22	.39	17.61	2.47	1.14
54	--	.01	1.91	.07	.05
55	.28	.46	37.24	5.69	2.02

TABLE 19 TOTAL EMISSIONS BY GRID FOR SEATTLE-TACOMA STUDY AREA

(Tons/Average Day)

Grid Number	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-carbon	Nitrogen Oxides
56	.77	.79	58.75	10.47	3.39
57	.21	.42	23.76	2.76	1.58
58	.27	.47	37.31	5.68	2.03
59	--	.01	1.91	.07	.05
60	.08	.15	14.74	1.48	.67
61	.45	1.32	41.85	6.58	3.59
62	.28	.35	17.56	2.17	1.08
63	.08	.12	19.52	1.79	.59
64	.35	.68	36.07	6.20	2.60
65	.10	.17	17.70	2.06	.79
66	.16	.27	24.19	2.59	1.20
67	.04	.04	3.97	.45	.18
68	--	--	.16	.01	.01
69	17.76	.76	7.59	1.17	1.59
70	.09	.11	4.01	.63	.32
71	.81	.22	19.85	1.42	1.23
72	.33	.70	38.46	6.36	2.63
73	.08	.15	13.95	1.41	.69
74	.17	.74	22.47	5.28	1.12
75	.30	.53	63.07	9.39	3.21
76	.77	1.26	22.58	9.36	1.67
77	19.21	14.04	32.06	13.84	16.51
78	1.45	4.71	5.70	3.74	1.76
79	.19	.25	2.23	.49	.28
80	.26	.33	14.24	2.19	.96
81	1.57	.73	20.52	4.23	1.85
82	.17	.32	5.82	1.09	.75

TABLE 19 TOTAL EMISSIONS BY GRID FOR SEATTLE-TACOMA STUDY AREA
(Tons/Average Day)

Grid Number	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-carbon	Nitrogen Oxides
83	.27	.77	39.53	7.57	.81
84	.03	.10	12.01	.58	1.24
85	.36	.46	18.86	2.76	1.31
86	.14	.40	26.99	2.24	1.77
87	.19	.35	23.95	1.99	1.55
88	.07	.20	13.45	1.11	.87
89	.04	.07	8.40	.67	.50
90	.15	.35	22.83	2.14	1.65
91	.06	.16	11.53	.96	.77
92	.04	.14	9.12	.76	.59
93	.37	2.54	22.30	2.04	2.36
94	.11	.32	21.57	1.79	1.42
95	.77	.83	5.64	.62	.51
96	.00	.00	.65	.05	.04
97	.00	1.01	1.20	.10	.07
98	.22	.52	37.17	3.10	2.50
99	.08	.19	14.24	1.23	.94
100	.05	.15	10.24	.85	.67
101	.04	.10	7.61	.63	.49
102	.03	.07	5.30	.44	.34
103	.01	.01	1.59	.13	.10
104	.00	.00	.63	.05	.04
105	.03	.07	6.06	1.00	.39
106	.04	.08	7.50	1.12	.47
107	.03	.07	6.10	1.01	.39

TABLE 19 TOTAL EMISSIONS BY GRID FOR SEATTLE-TACOMA STUDY AREA

(Tons/Average Day)

Grid Number	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-carbon	Nitrogen Oxides
108	.04	.05	3.05	.45	.20
109	.03	.01	1.59	.23	.10
110	.01	.01	1.78	.06	.05
111	.04	.06	8.36	.66	.27
112	.09	.11	9.85	1.15	.49
113	.02	.06	4.84	.70	.31
114	.04	.05	3.41	.53	.22
115	2.15	.41	20.36	4.19	1.78
116	.01	.02	2.28	.39	.13
117	.01	.01	1.15	.09	.07
118	--	--	.05	--	--
119	4.50	3.85	12.89	5.91	1.82
120	18.90	2.44	35.52	12.12	5.90
121	.07	4.25	4.25	.65	.27
123	.06	.21	13.37	1.10	1.01
124	.05	.16	10.03	1.63	.70
125	.09	.09	5.65	.77	.37
128	.33	.29	8.77	1.35	.65
129	.12	.12	8.03	1.27	.51
130	76.46	7.18	33.30	10.60	12.79
133	.06	.03	.09	.01	.02
135	45.49	6.24	48.42	13.87	6.51
139	.05	.04	2.03	.37	.13
140	.08	.07	5.07	.83	.32
141	.08	.07	5.09	.83	.32

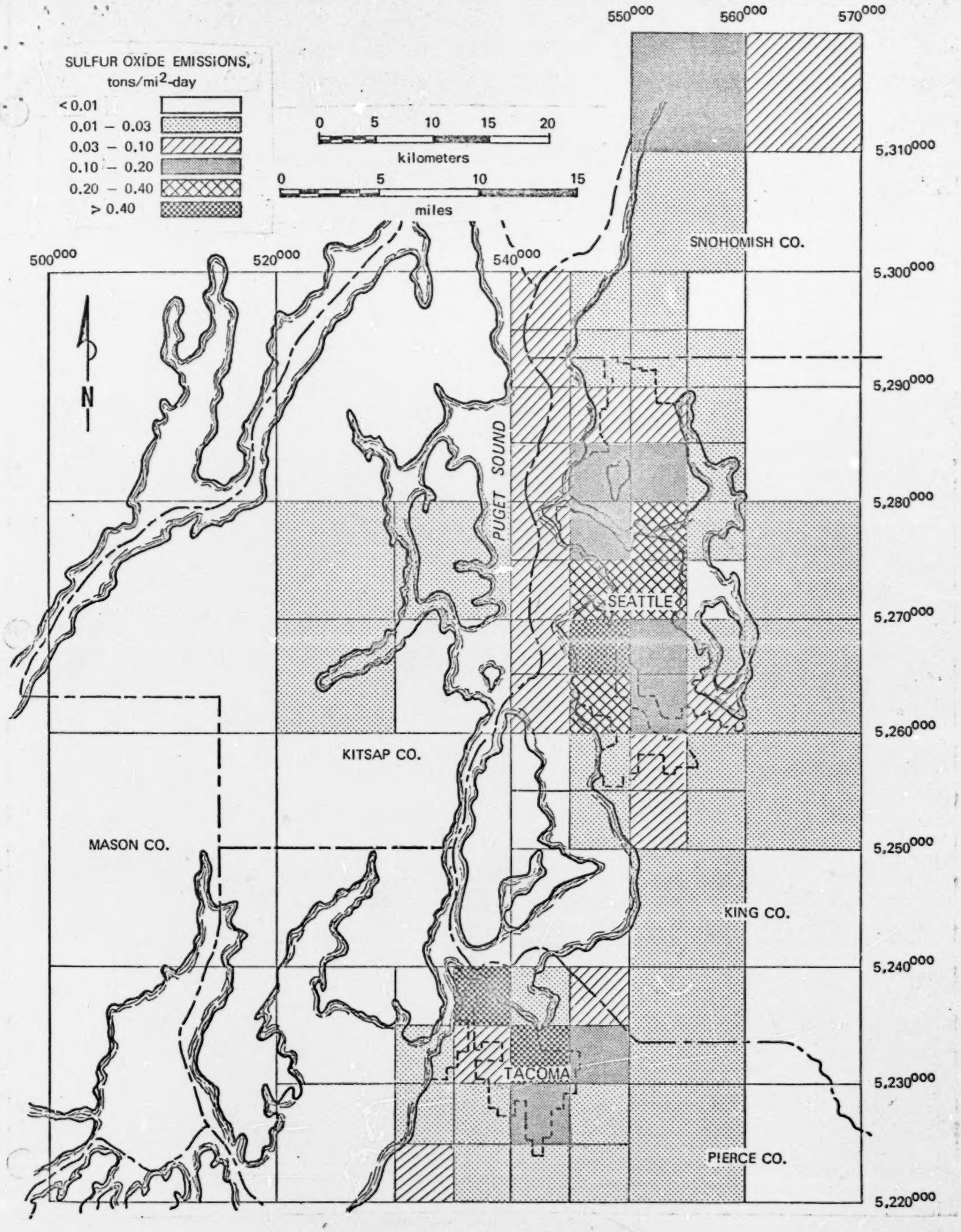


Figure 4. Sulfur oxide density.

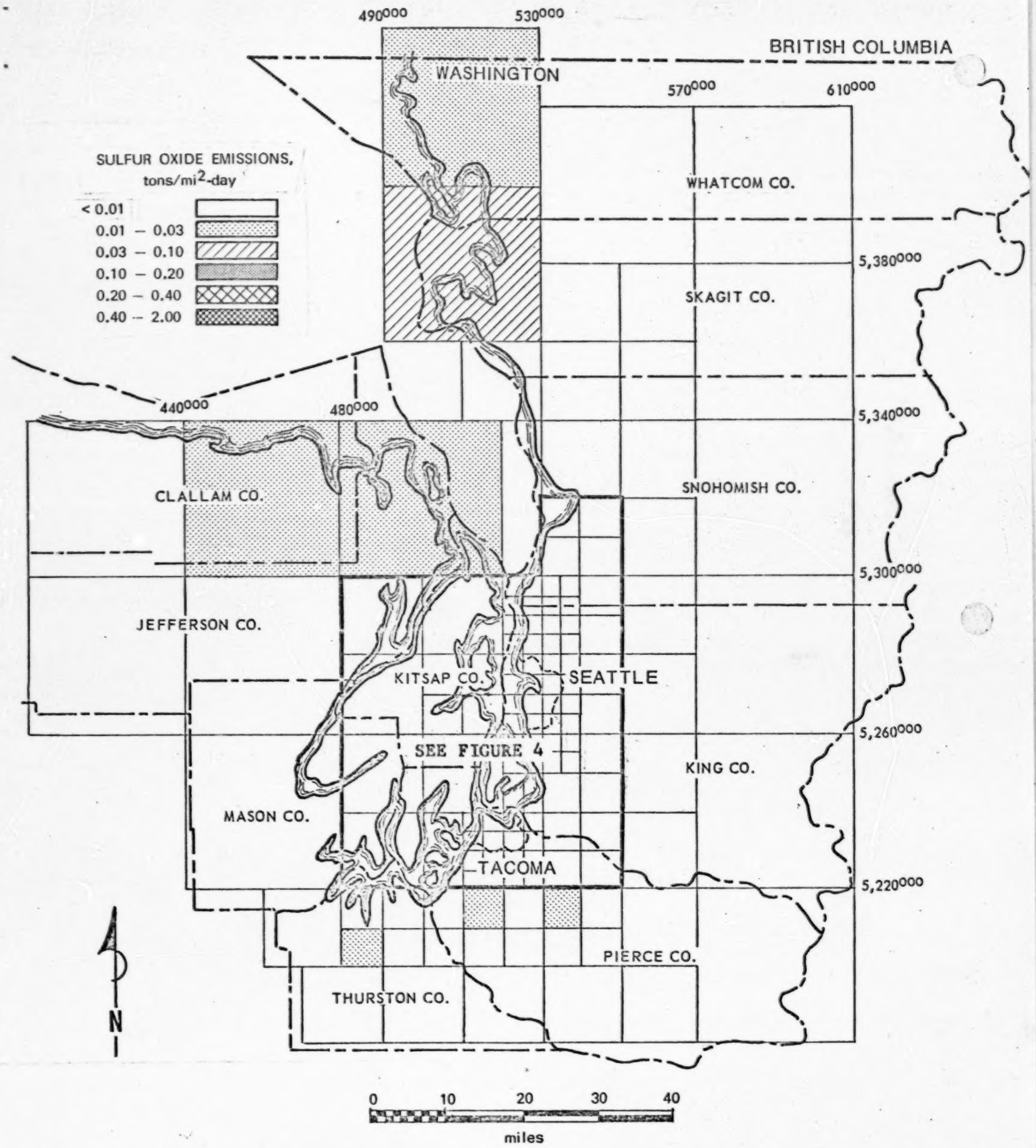


Figure 4A. Sulfur oxide emission density from all sources.

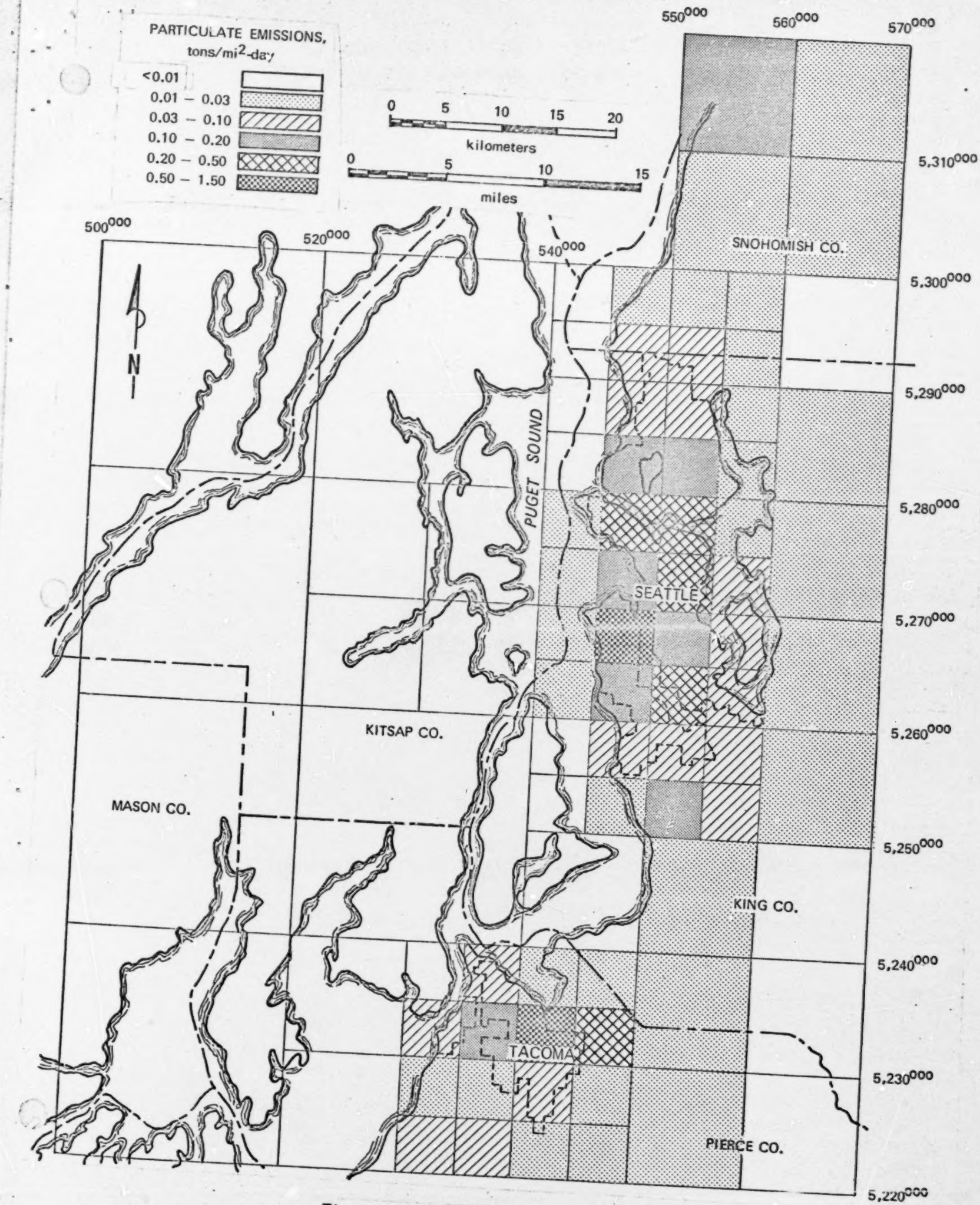


Figure 5. Particulate emission density.

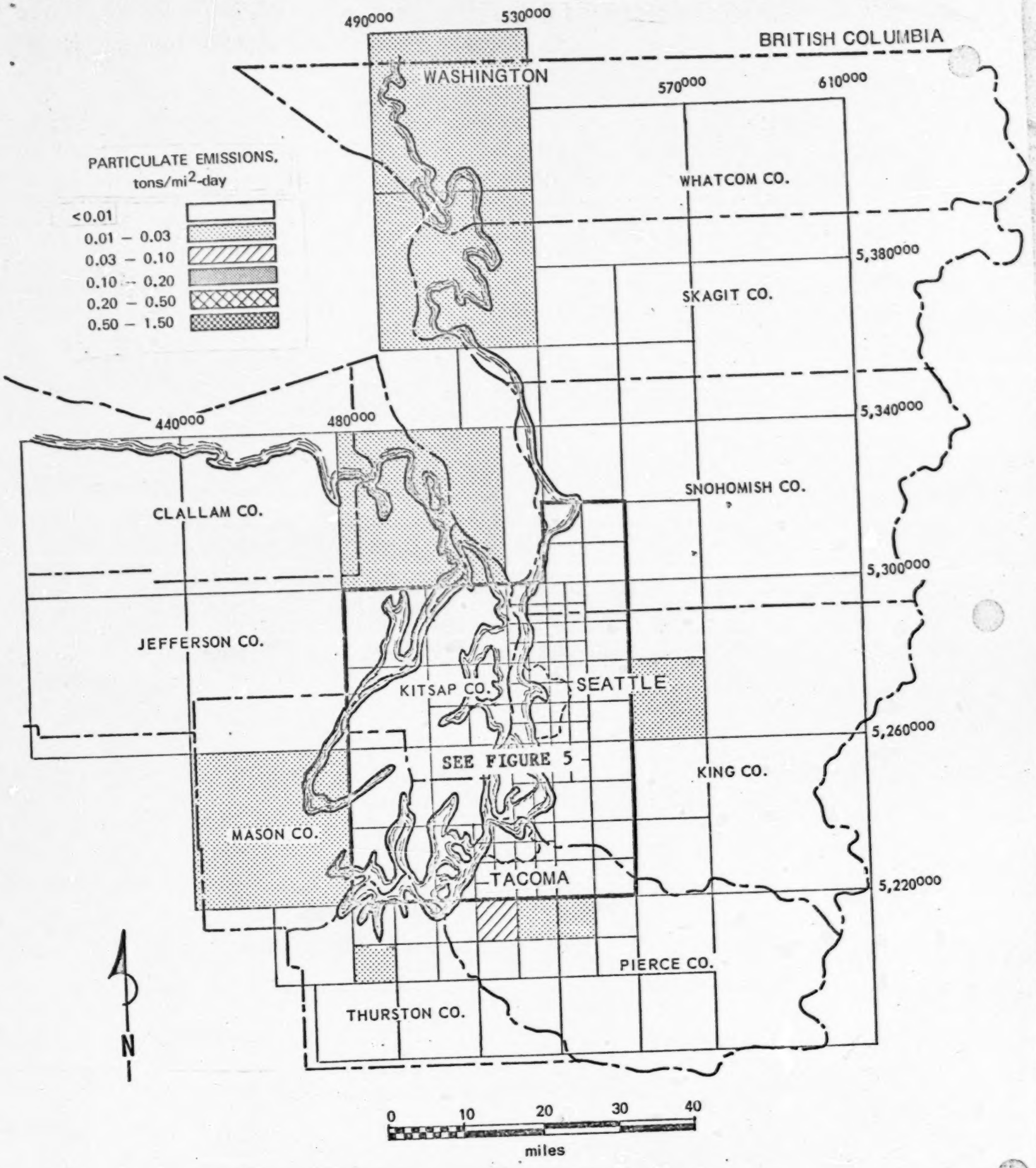


Figure 5A. Particulate emission density for all sources.

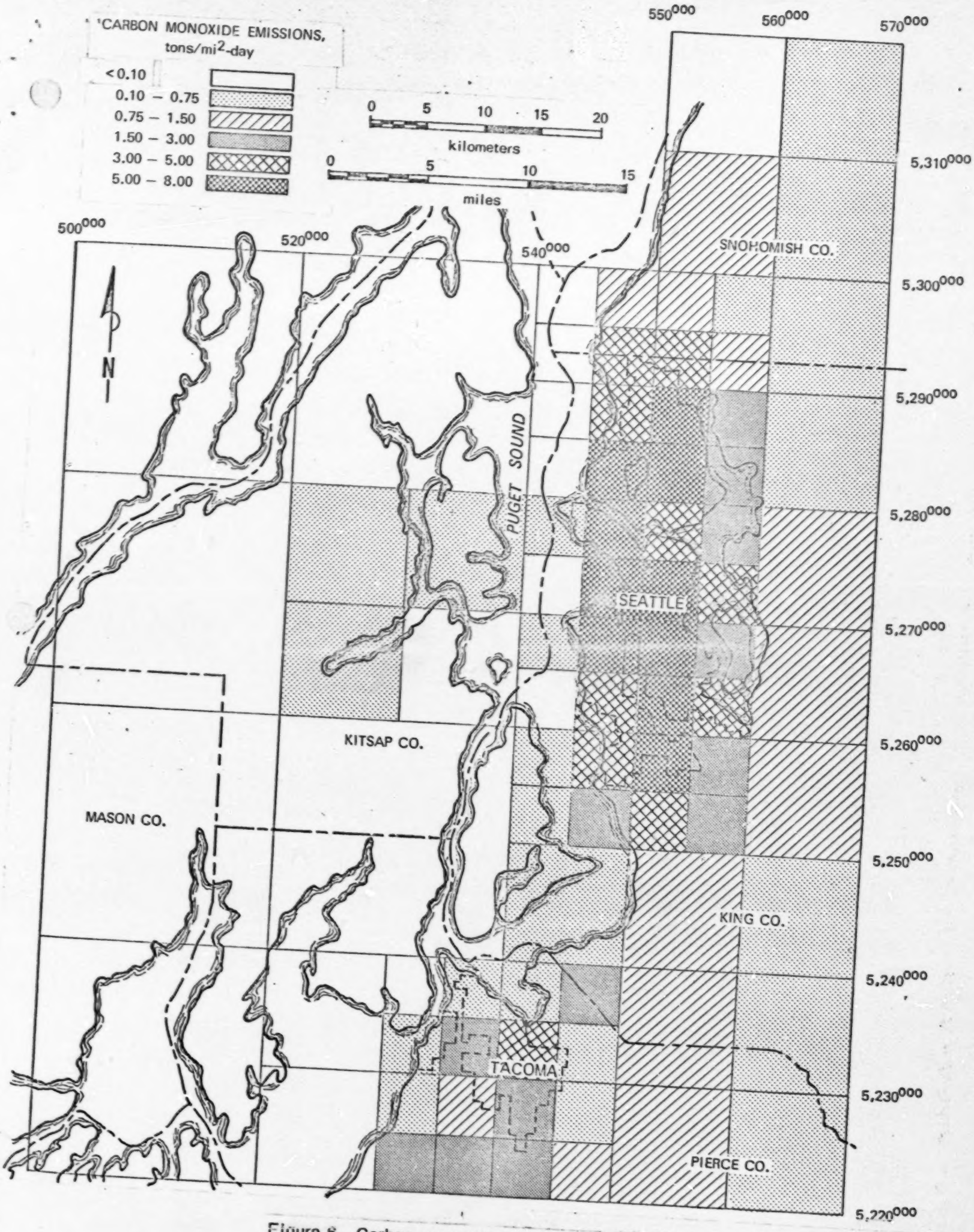


Figure 6. Carbon monoxide emission density.

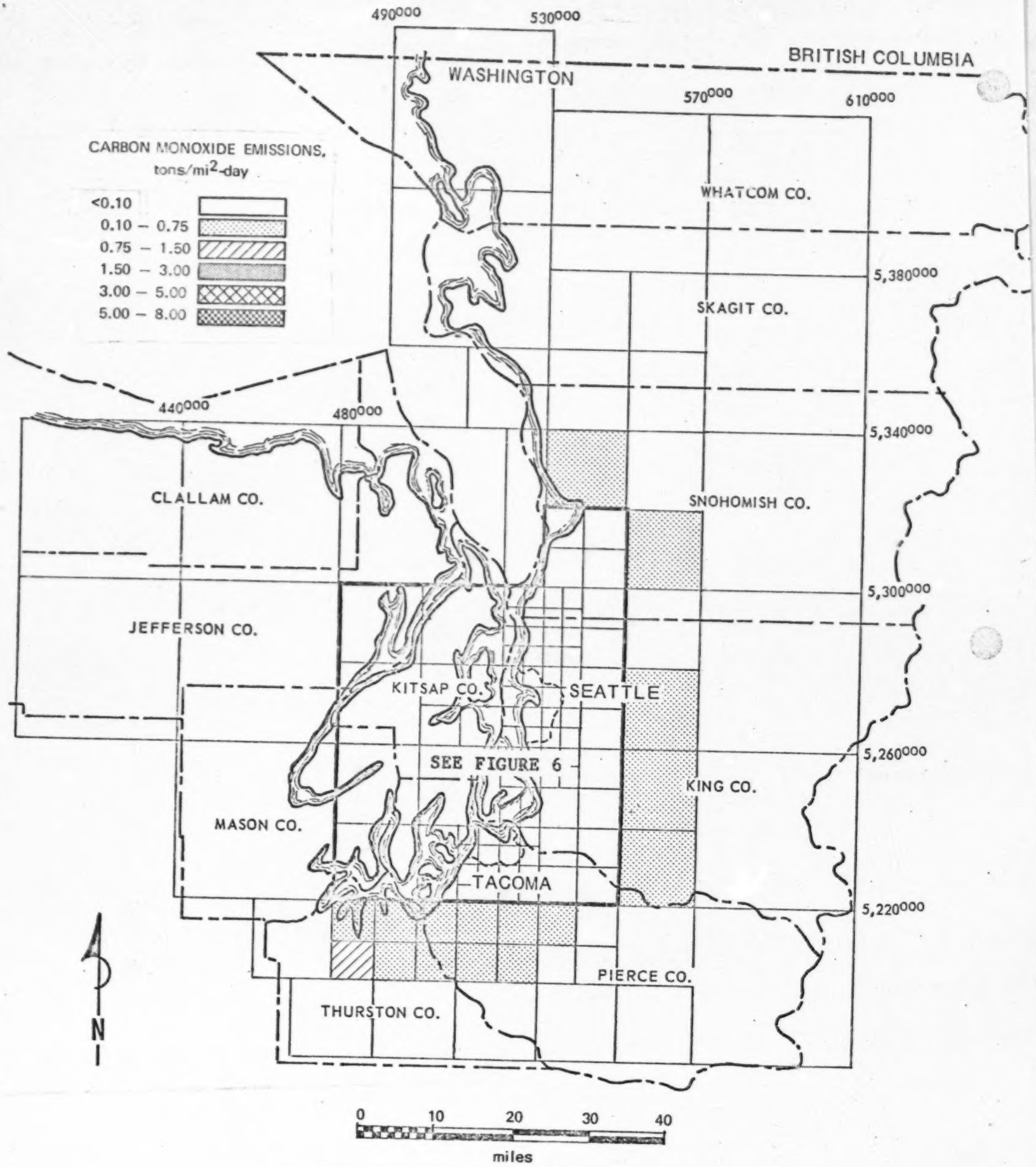


Figure 6A. Carbon monoxide emission density for all sources.

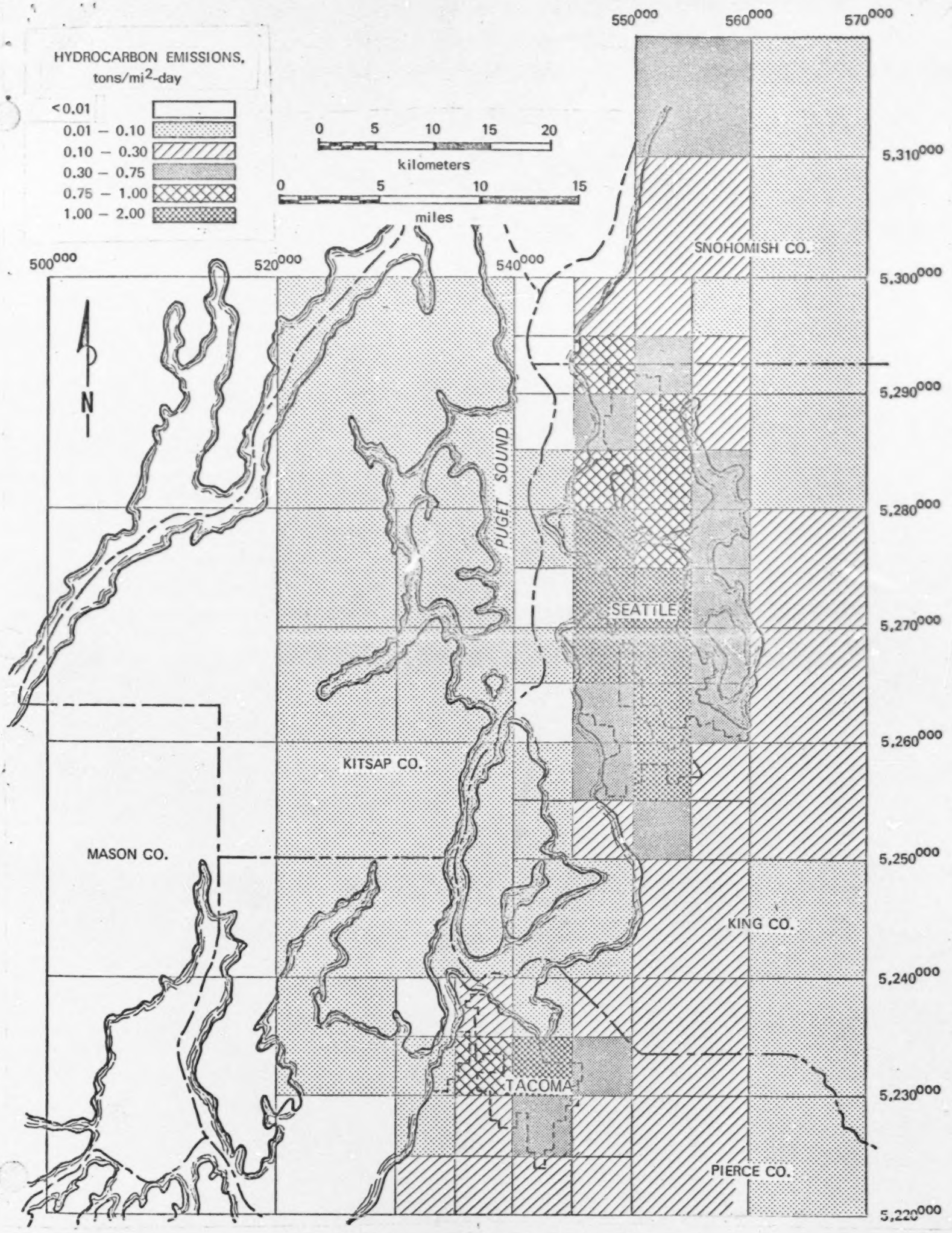


Figure 7. Hydrocarbon emission density.

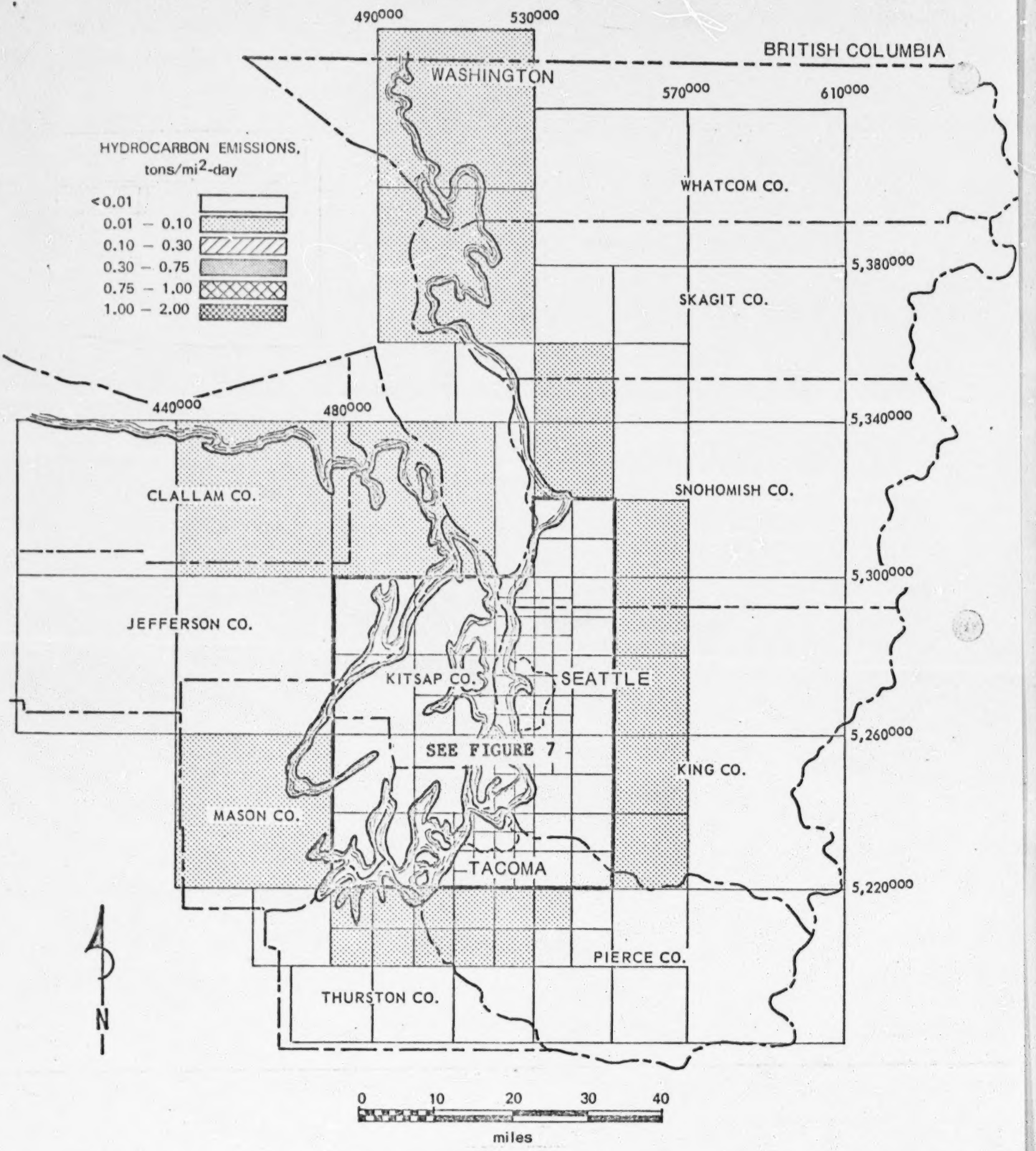


Figure 7A. Hydrocarbon emission density for all sources.

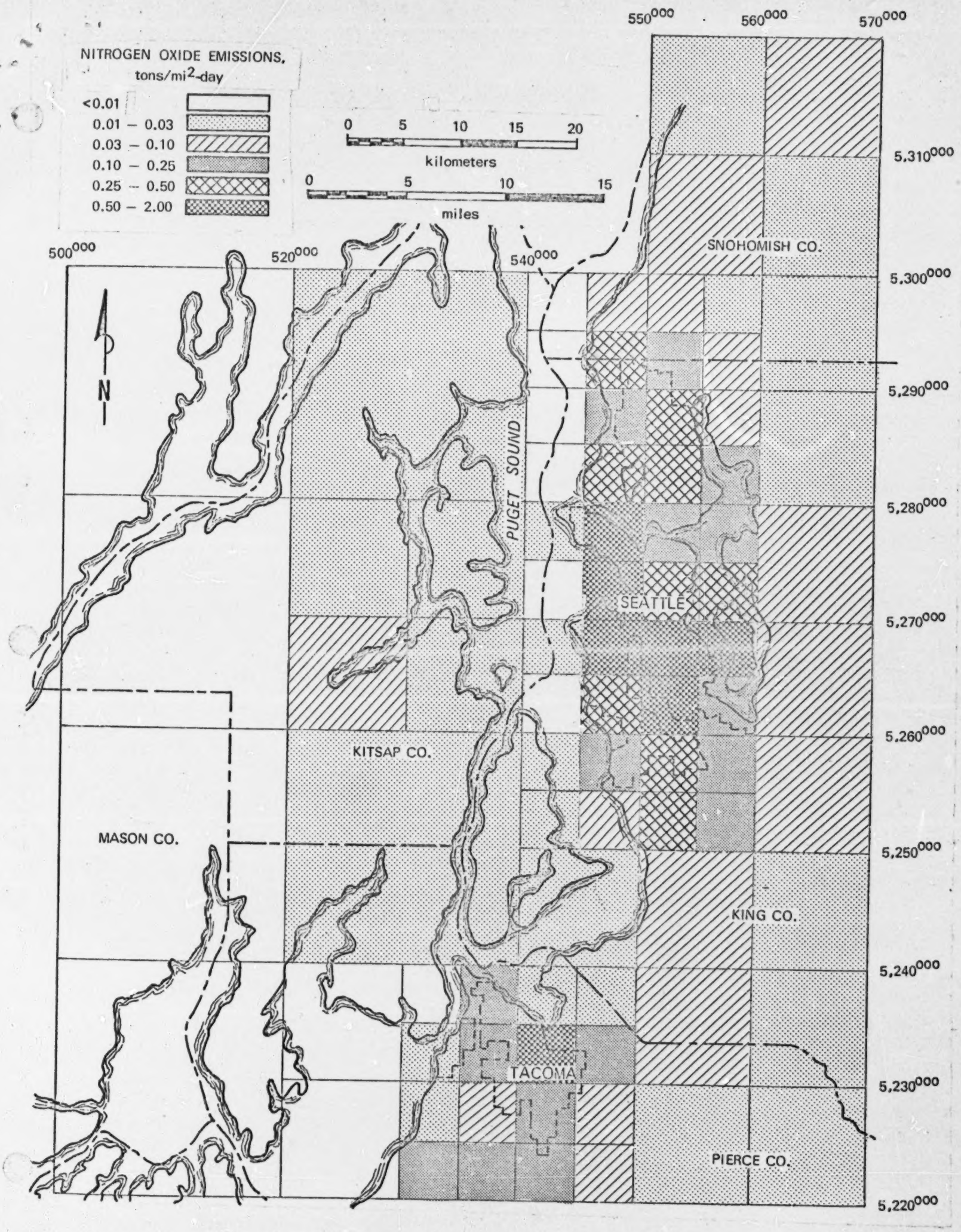


Figure 8. Nitrogen oxide emission density.

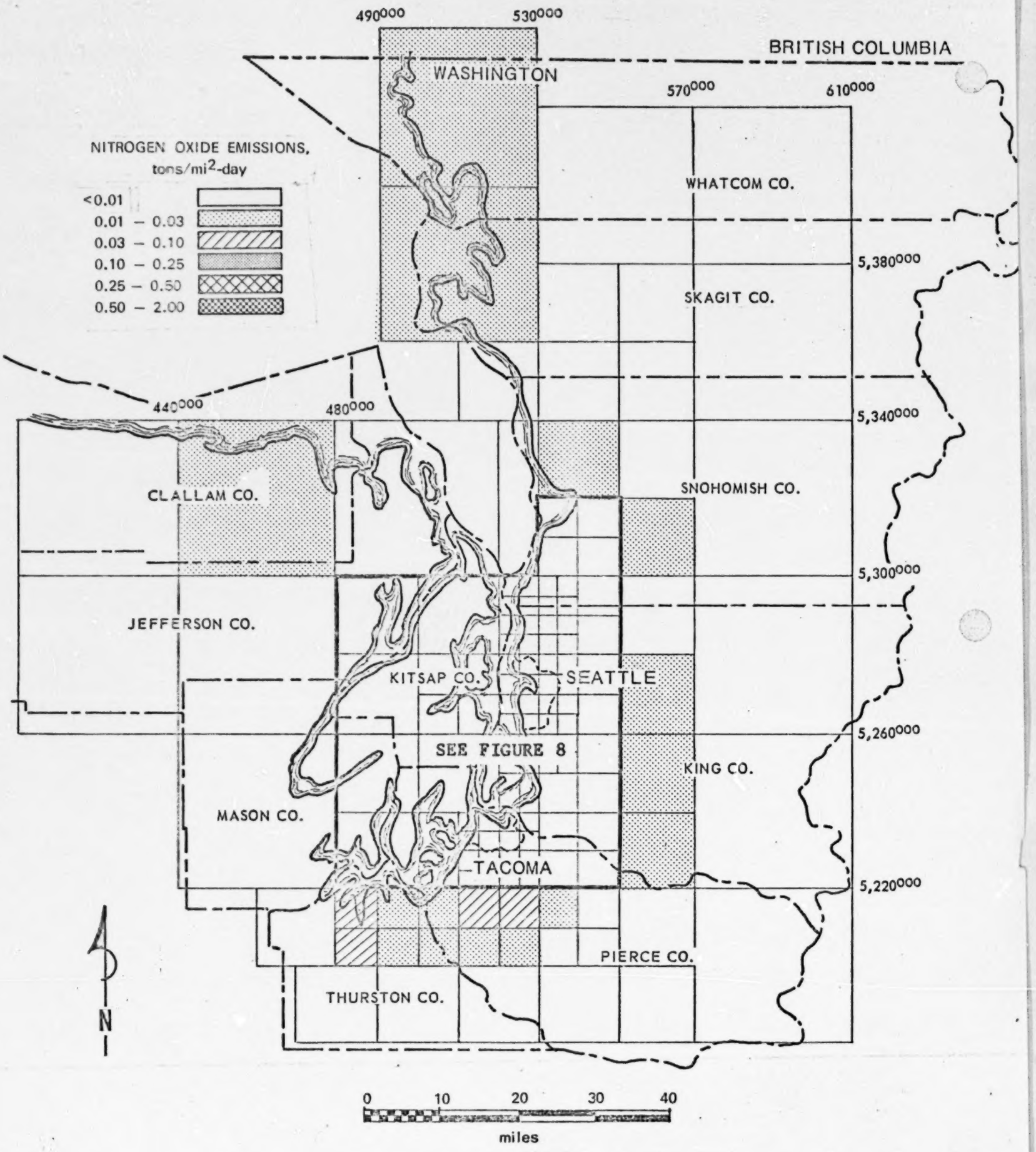


Figure 8A. Nitrogen oxide emission density for all sources.

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